Montana wheat and barley acreage supply functions : the effects of Federal farm commodity programs
by Robert Gene Aukes

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in APPLIED ECONOMICS
Montana State University

Abstract:
This study is an analysis of the effects of various government farm commodity program policies on Montana wheat and barley acreages planted for harvest from 1961-1973. This analysis was facilitated by specification and estimation of Montana wheat and barley acreage supply functions.

An important part of this analysis was the construction of variables capable of expressing relative value and attribute information of the government program policies of the 1961-1973 period. On this basis, variables representing weighted diversion payment rates and weighted price supports were constructed. Montana wheat and barley acreage supply functions were specified, and were estimated by ordinary least squares regression analysis. Effects of farm commodity program policies on Montana wheat and barley acreages were analyzed by calculating elasticities of Montana wheat and barley acreage supply with respect to all explanatory variables, including policy variables.

Important conclusions of this study are: Montana farmers are very unresponsive to diversion or set-aside payment rates while making wheat and barley planting decisions, and Montana farmers are generally more responsive to relevant market prices than has been indicated by national and other regional studies.

MONTANA WHEAT AND BARLEY ACREAGE SUPPLY FUNCTIONS:

THE EFFECTS OF FEDERAL FARM COMMODITY PROGRAMS

by

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A thesis submitted in partial fulfillment
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of

MASTER OF SCIENCE

in

APPLIED ECONOMICS

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MONTANA STATE UNIVERSITY
Bozeman, Montana

February, 1977

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ACKNOWLEDGEMENTS

I wish to express my indebtedness to the chairman of my committee and graduate advisor, Dr. John Marsh, for his valuable assistance, guidance and encouragement during my graduate career and in preparing this thesis. My appreciation is also extended to Professor Maurice Taylor for his valuable advice and his accessibility throughout my graduate program, to Dr. Gail Cramer and to Dr. Clyde Greer, who were members of my committee.

I wish also to thank Mr. Jim Ross for his assistance, and Mrs. June Freswick and Mrs. Evelyn Richard for preparing the final manuscript.

Finally a special thanks must go to my wife Tara for her support.

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ABSTRACT

This study is an analysis of the effects of various government farm commodity program policies on Montana wheat and barley acreages planted for harvest from 1961-1973. This analysis was facilitated by specification and estimation of Montana wheat and barley acreage supply functions.

An important part of this analysis was the construction of variables capable of expressing relative value and attribute information of the government program policies of the 1961-1973 period. On this basis, variables representing weighted diversion payment rates and weighted price supports were constructed. Montana wheat and barley acreage supply functions were specified, and were estimated by ordinary least squares regression analysis. Effects of farm commodity program policies on Montana wheat and barley acreages were analyzed by calculating elasticities of Montana wheat and barley acreage supply with respect to all explanatory variables, including policy variables.

Important conclusions of this study are: Montana farmers are very unresponsive to diversion or set-aside payment rates while making wheat and barley planting decisions, and Montana farmers are generally more responsive to relevant market prices than has been indicated by national and other regional studies.

Chapter 1

INTRODUCTION

Montana wheat and barley production has taken place in an environment dominated by national agricultural commodity programs for the past several decades. The intent of these programs has been to effect changes in many phases of the agricultural production and agricultural marketing sectors, to effect changes in the market for agricultural inputs, and to change certain existing conditions of farm life in general. The desired changes of these programs have ranged from increased market prices for commodities and increased returns to factors of production, to reduced and more or less stabilized supplies of the agricultural commodities in question. The primary concern of program formulators has been increased welfare of the agricultural community.

Competing goals and policies of agricultural legislation are apparent when reviewing past policy. This characteristic of competing goals and policies has tended to compound, or even create, problem areas in agriculture. Past farm problems have been defined as price problems, supply problems, farm income problems, over-production problems, or return on investment problems; attacking one of these has invariably aggravated another.

In discussing the nature of the real farm problem, Shepherd describes it as an agricultural adjustment problem that results from two basic elements: Continued overproduction of farm products relative to the demand for them, keeping national farm income low, and low per capita farm income due to an excessive supply of farmers.[1]

The Problem

This thesis addresses the first element of the farm problem as defined by Shepherd. It attempts to identify and measure the effects of farm production control provisions on wheat and barley acreages planted in the State of Montana.

Unique climatic, geographical, and institutional factors influence agricultural production and marketing practices in the State of Montana. It is not unreasonable to assume that certain institutional production parameters, such as national agricultural production control policies, would influence Montana agricultural production differently from that of the remaining U.S.

This thesis concerns the existing understanding of the effects of farm production control legislation on annual production of Montana wheat and barley. It also concerns the differences of these effects observed between Montana and other production regions.

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[1] Geoffrey S. Shepherd, Farm Policy: New Directions, (Ames, Ia.: Iowa State University Press, 1964), p. 90.

The farm programs examined in this study were those developed and enacted between 1961 and 1973, a period during which farm commodity surpluses were at record levels. During this period, control of agricultural production appeared to be the primary objective of agricultural policies. Nonetheless, keeping in mind past programs and their numerous and conflicting goals, one must note that elements in these programs deviated from strictly a production control objective. Maintenance of farm income and reduction of government costs were major auxiliary concerns.

Justification

Wheat and feed grain policies, very important factors determining the organization of agricultural production in the State of Montana, become the most important factors determining the organization of agricultural production during periods of wheat and barley surpluses and depressed market conditions.

Recent research employing national data has identified and empirically measured the relevant farm commodity program policy variables that significantly affect acreages of most major feed grains and wheat in the United States (US). Much of this work was focused on the voluntary farm commodity supply controls of the 1960's, in the belief that future farm legislation would be of a form similar to these programs. The voluntary nature of these programs and provisions of the set-aside program (1971-1973) whereby producers could plant any crops after meeting certain basic set-aside requirements are thought to have increased the difficulty of measuring producer responses to adjustments in program provisions.

Past research of this nature has focused on the analysis of acreage supply relationships for wheat and the feed grains, and the development of theoretical models for evaluating farm commodity program effectiveness. The effect of relevant market prices on acreages of wheat and feed grains, and the effect of support prices and acreage restrictions for competing crops on acreages of wheat and feed grains was also measured.

A considerable body of theory was developed in the construction of policy variables which would accurately represent the quantitative framework of the wheat and feed grain programs. The purpose of constructing policy variables from measurable program data was to simplify the model, incorporating more than one measurable term into a single term subject to empirical measurement or estimation. Statistical models included policy variables and relevant market prices as explanatory variables in a model with acres of a specific crop as the dependent variable. The net effect of all other acreage supply determinants and random effects was assumed to constitute a mean-zero random variable with constant and finite variance over the sample period. This assumption permitted the use of ordinary least squares for measuring individual effects of the specified variables.

Analysis of the effects of farm program policy variables and market prices on acreages of wheat and feed grains analyzed at the national level may not accurately identify and measure the variables relevant at a given regional level (the State of Montana). Regional characteristics of agricultural organization that appear relevant to Montana would include: (1) Soil and climatic conditions requiring specific production practices and permitting less substitutability among crops in production; (2) existing regional production functions which may differ from production functions of other areas due to differences in technology and the natural resource base; (3) regional characteristics of both primary and derived demand for wheat, feed grains, and their substitutes in production and consumption; (4) locational characteristics of the region, implying differences in costs of transporting farm commodities to the major consuming centers.

Given that the existing set of economic and institutional factors that determine acreages of wheat and barley planted in the State of Montana is unique, identification and measurement of the relevant farm commodity program policy variables as they influence Montana wheat and barley production would appear justified. Information pertaining to supply of wheat and barley production in

Montana, and producer responses to both market prices and farm commodity program policies are needed.

Objectives

The primary objective of this thesis is to provide information required for evaluating past government farm commodity supply control programs, and to suggest a farmework for evaluation of such farm programs in the future. Specific objectives of this thesis are:

1. Identification and empirical measurement of underlying structural relationships between wheat and barley acreage in the State of Montana, especially as related to government farm commodity programs.
2. Estimation of own price and cross elasticities of supply for wheat and barley in Montana.
3. Determination of the marginal rates of transformation in production between wheat and barley in the State of Montana over the time period studies.

Methodology

Annual time series data on production, market prices, and farm commodity programs relevant to Montana wheat and barley were collected for the priod beginning in calendar year 1961 and extending through

1973. Data gathered from administrative interpretations of the annual wheat and feed grain programs was used to construct policy variables capable of capturing quantitative magnitudes and variations in these programs. Complete descriptions of all variables employed in this study will be found in Chapter 2. The explanatory variables employed in the acreage supply functions of wheat and barley were specified on the basis of economic theory and observed production practices. Since the objectives of this study center on identification and measurement of acreage supply determinants, multiple regression analysis was chosen as the method of investigation.

A brief historical survey of past farm commodity legislation is presented in the second chapter of this thesis. This survey begins with the Federal Farm Board of 1929, and it discusses the farm problem, objectives of farm policy, and the effects of this policy on agriculture. Chapter 3 presents the theory of supply. In Chapter 4 is found the construction of variables representing certain agricultural policies. Also presented in Chapter 4 are econometric theory, development of the general linear model, analysis of certain statistical problems, and discussion of related research. The estimated Montana wheat and barley acreage supply functions are presented in Chapter 5. Also discussed are the significance and magnitude of the estimated coefficients. Chapter 6 presents a summary and concluding remarks.

Chapter 2

HISTORICAL REVIEW OF AGRICULTURAL LEGISLATION

Major farm commodity legislation originated with the onset of the 1929 depression and has remained within the institutional structure of agriculture to this day. Early farm commodity legislation was directed primarily toward the control of food and feed grain surpluses. In 1929 the Federal Farm Board was empowered by Congress to make loans to cooperatives for the purpose of controlling grain surpluses by purchasing excess supplies and constructing new storage facilities. Cash advances were made to farmers for their crops, thus indicating some farm income objectives of this early program.

The development of farm commodity programs since 1929 has been shaped by certain basic problems of American agriculture and by problems caused by the programs themselves. Different programs have had varying goals from year to year, depending on the particular problem at hand. In recent years farm commodity legislation has encompassed a wider range of goals to include consumer interests, market structure issues, and world trade issues.

Stable supplies and prices of wheat and feed grains is a goal of commodity programs desired by commercial farming interests, the livestock industry, the food processing industry, consumers and the federal government.

Inherent in the Agricultural Marketing Act of 1929 and all major farm commodity programs since that time is an assumed imbalance of supply and demand of food and feed grains. Periods of scarcity of these grains in the U.S. have occurred during major wars or during periods of drought in heavily populated countries which required substantial food relief. These periods have seen a depletion of stocks or reserves. The livestock industry which utilizes feed grains as a primary input experienced disruption during these periods as a result of violently fluctuating factor prices; however, domestic consumption of primary food and feed grain products has never been threatened by an inability of American agriculture to produce an adequate supply of these grains. Unless there is an extreme outward shift in demand for wheat and feed grain exports, or conditions which require a large relief effort, inability to produce an adequate supply of wheat and feed grains is not a problem of American agriculture.

Historically, overproduction of wheat and feed grains (excess production capacity), with its accompanying large stocks or surpluses, has been the dominant problem in American agriculture. Excess capacity is defined by Tweeten as "the surplus of production capacity over market utilization at socially acceptable prices."[2] Excess production capacity with the accompanying grain surpluses and depressed market prices leads to farm incomes judged by agricultural policymakers to be socially unacceptable. Stabilizing farm incomes at some level deemed acceptable by agricultural policymakers has been a primary goal of farm commodity programs over the past several decades.

Associated with excess capacity and the resulting wheat and feed grain surpluses are other social problems. The cost to society of storing excess supplies of grain has often been determined as a primary farm commodity problem, and a problem at which farm commodity legislation was directed. Given a carry-over of wheat in July of 1960 of 1.4 billion bushels, or a carry-over of corn in October of 1961 of 2.0 billion bushels, it can be seen that the cost of storage facilities of this scale could be burdensome to society.[3]

The concern for efficient resource allocation in reference to the resources employed in grain storage seems valid; however, a more pressing problem appears to be inefficient resource allocation in reference to wheat and feed grain production in surplus

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[2] Luther Tweeten, Foundations of Farm Policy, (Lincoln, Nebr.: University of Nebraska Press, 1970), p. 155.

[3] Ibid., p. 309.

quantities. The existence of given quantities of commodities not clearing the market at some established minimum price level, or simply the existence of a price floor not allowing market prices to fall to an equilibrium level, would signal a market misallocation. Estimates of excess production capacity in agriculture in the period 1956-1966 fall between 5-10 percent of farm output. Estimates of excess supplies of individual farm resources have found farm labor to be in relatively greatest excess. From 1952-1961, approximately 40 percent of all agricultural labor was estimated to be in excess supply. A continuing goal of agricultural policy has been the efficient allocation of resources. While past policies have supported farm prices, farm receipts, and net farm income, they have not substantially slowed the outflow of labor from agriculture.[4]

Feed and food grain reserves and excess production capacity have proven to be beneficial to the U.S. economy in periods of war and world food emergencies. Because of high capital costs and uncertainty, it cannot be assumed that private enterprise would provide some socially desirable level of either grain stockpiles or excess productive capacity. Thus, food reserves and agricultural productive capacity are concerns of national agricultural policy.

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[4]Ibid., pp. 156, 168, 324, 328.

Stability and support of farm commodity prices and farm incomes has been a major goal of agricultural policy since 1929. In the 1920's and 1930's the agricultural problem was diagnosed as a problem of farm commodity price instability as prices received by farmers varied considerably more than did prices paid by farmers. This price instability problem evolved into a problem of low prices of farm commodities during the industrial depression of the 1930's, and different price support tools of agricultural policy have been employed continually to this day.

Domestic price instability of food and feed grains is caused by unstable export demand, livestock production cycles, and highly variable supplies of grains as a result of exogenous forces affecting growing conditions. The problem is accentuated by the fact that demand for farm products is very inelastic. The problem of low farm commodity prices is due to the continued presence of excess production capacity and expanding supplies of farm commodities in the face of this higly inelastic demand. Increasing price flexibility in recent periods in the presence of increased excess capacity and decreasing income elasticy of farm products has tended to worsen the condition of low and unstable farm commodity prices.

It is felt by most agricultural economists that the agricultural problem was incorrectly diagnosed as a price problem, and that price support measures may have impeded the necessary resource adjustments required for long run income stability of farmers.[5]

Low prices are not the problem, but a symptom of the problem. Despite this, price supports have had a major impact on aggregate farm income and remain in present agricultural programs.

Price support measures have generally been tied to some form of production controls, and benefits of price support programs have been distributed among farmers in proportion to their sales or production. For this reason the problem of rural poverty has been poorly addressed by price support programs, with the lion's share of program benefits being received by the group of farmersthat controls the major portion of farming's resource base. The problems of supply control of feed and food grains and rural poverty are related but separate issues, and it should not be expected that these two different situations can be corrected with one set of actions.

The choice between voluntary and mandatory supply controls is a decision that must be made if farm income is to be increased through supply control mechanisms. The term "mandatory" may over-emphasize restrictions on the freedom of farmers, because in the past supply control programs have become mandatory only if approved by a substantial majority of producers in a referendum vote. Given

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[5]Shepherd, p. 34.

a supply control program in the presence of excess production capacity and excess supplies of feed and food grains, increments to farm income can be attained from either larger consumer outlays or larger Treasury costs. In the past, mandatory control programs have tended to increase farm income through the market while voluntary control programs imply greater Treasury costs. Mandatory control programs represent a regressive "tax" on consumers by increasing food expenditures. Low income consumers spend a higher proportion of their incomes on food than do more affluent consumers, and would therefore bear a relatively larger portion of program costs. Mandatory control programs also have relatively high administrative costs, tend to freeze production patterns which may be inefficient, and tend to restrict the freedom of farmers to produce and market their commodities. Voluntary control programs are supported with funds from the Treasury and therefore represent a progressive form of taxation on consumer-taxpayers.

The general tendency of farm commodity legislation in the U.S. has been a growing commitment of the federal government to support farm income. The voluntary supply control programs, commodity storage programs, and direct payments used in the past to facilitate this commitment have resulted in high Treasury costs. It is a goal of agricultural policymakers to minimize Treasury costs of farm commodity programs without depressing farm incomes to unacceptable levels.

In ranking farm commodity programs in terms of efficient use of government dollars, Tweeten ranks mandatory supply control programs as being the most efficient, followed by long-term land retirement, short-term land retirement, direct payments, and lastly commodity storage.[6]

A more recently stated goal of farm commodity legislation is reliance on the market for determining efficient production patterns. Crop by crop allotments were eliminated. This enabled farmers to maximize income by growing crops they can grow most efficiently. Under earlier programs, farmers attempted to maximize income by diverting acreage from the production of commodities whose supply was controlled by government programs to the production of commodities whose supply was not controlled. Supply controls on specific commodities were found to be much less effective in attacking the farm income problem if cross-compliance with all other existing farm commodity supply control programs was not enforced.

In international trade, the U.S. has long had both a comparative and an absolute advantage in the production of feed and food grains.

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[6]Tweeten, p. 346.

Due to a recent increase in export demand and abundant domestic production, U.S. exports of feed and food grains have helped to maintain and improve the balance of payments position of the U.S. in international trade. Maintaining a competitive position in world markets through exports of farm commodities has become a primary goal of U.S. agricultural policy.

In 1929 the Federal Farm Board employed the technique of purchase and storage to attack the perceived problem of excess supplies and low prices of farm commodities. With a revolving fund of $500 million, the Board made loans to cooperatives. Regional marketing cooperatives were developed to prevent and control surpluses of certain commodities and to prevent extreme price responses to existing surpluses or shortages. Provisions of the Agricultural Marketing Act were broadly interpreted, justifying the attempted maintenance of U.S. wheat and cotton prices at a level above world market levels. According to J.S. Davis in December, 1930, domestic wheat prices would have been 30 to 40 cents lower without the program.[7] However, the Board's operating funds were soon exhausted and all domestic grain prices moved with world prices to the lowest level in history.

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[7]Rainer Schickele, Agricultural Policy: Farm Programs and National Welfare, (New York: McGraw-Hill Book Co., 1954), p. 189.

In its failure, the Federal Farm Board learned that a very large quantity of feed and food grains must be purchased if a noticeable effect on the market is to be made. This observation is consistent with the contemporary theory that price levels of feed and food grains are dependent upon carryover levels. For future reference, the Board also recommended that effective production controls must accompany any effort to maintain grain prices. The Federal Farm Board was abolished in 1933.

The Agricultural Adjustment Act, enacted in 1933, authorized strong policies for the purpose of raising farm prices and incomes. In addition to the objectives of bringing immediate relief to farm families and increasing farm income, the failure of the Federal Farm Board convinced policymakers that price-depressing surpluses must be prevented by the use of production controls.

The domestic allotment plan was the name of the wheat program in the Agricultural Adjustment Act. The domestic allotment plan was comprised of production controls and income distribution. The production control mechanism consisted of a contractual agreement between farmers and the USDA for the farmers to reduce their average wheat acreage by as much as 20 percent depending upon the existing supply situation. In return for this reduction of wheat acreage, farmers were guaranteed adjustment payments on that proportion of their wheat to be used for domestic food. Certificates were issued to farmers for their allotment (that portion of their wheat production to be used for domestic food), and these certificates were sold by farmers for a value equal to the difference between market price and some assumed "fair" price established by policymakers.[8] Adjustment payments were designed to equal the difference between market price and the parity price on allotment production only. The parity price would be the average price for wheat during the 1910-1914 base period multiplied by a current prices paid or parity index number. Adjustment payments were made on about 54 percent of the wheat production of producers who complied with the production controls. The certificates were purchased by millers or other processors with the purchase of food wheat and hence constituted a use tax on wheat.

In the feed grains arena, the Agricultural Adjustment Act employed both production controls and income distribution provisions. Nonrecourse loans facilitated the income distribution objectives. Nonrecourse meant that the advance loans made to farmers on given commodities, at some rate per unit of commodity, need not necessarily be repaid. If the market price of this given commodity remained below the loan rate, farmers could deliver the commodity to the

[8]Don F. Hadwiger, Federal Wheat Commodity Programs, (Ames, Ia.: Iowa State University Press, 1970), p. 122.

Commodity Credit Corporation as payment of the loan. If the market price of the commodity in question were greater than the loan rate, farmers could sell the commodity on the open market and repay the loan. The Commodity Credit Corporation was a government financed corporation created in 1933 by executive order. The loan rate was adjusted to some ratio of parity price and constituted a price floor for those farmers who complied with the accompanying production controls. Barley was not a feed grain included in this program. Nonrecourse loans were used in subsequent feed and food grain programs and have remained in these programs as major policy tools until quite recently.

Allotments for the domestic allotment plan were based on the average wheat acreage raised on each farm during a base period extending from 1930 to 1932. Farmers who had not grown wheat during this period received no allotment and no certificates. In addition to bringing no income relief to farmers who had planted no wheat during the base period, the plan tended to lock resources into a rigid production pattern without regard for economic efficiency.

Another difficulty of the Agricultural Adjustment Act was that the processing tax on food wheat was regarded as a tax on bread. This tax was regressive in nature in that lower income families spent a larger proportion of their income on staples such as bread than did higher income families.

It was felt by policymakers that the Agricultural Adjustment Act would not stimulate production as much as the policies of the Federal Farm Board had because price subsidies covered only part of the existing production and not any additional or marginal production. Also, because the domestic allotment was based on past production, it was felt that present or future production decisions would be relatively unaffected. Economist John D. Black disagreed with these ideas, basing his argument on traditional marginal analysis. He theorized that price subsidies would help to cover most of the fixed costs in farming and farmers would expand production as long as returns on additional acres exceeded variable costs on these acres.[9]

Weather proved to be the main influence on production and prices of feed and food grains from 1933-1935. The problem with voluntary controls of the Agricultural Adjustment Act can be exemplified by the fact that while complying farmers reduced their wheat acres by 19 percent in 1935, noncomplying acreage increased by 70 percent.[10] It was generally concluded that if voluntary controls were to be effective, more persuasive incentives would have to be offered. In 1936, the U.S. Supreme Court ruled the

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[9] Ibid, p. 123.

[10] Ibid, p. 128.

production control and processing tax features of the Agricultural Adjustment Act unconstitutional.

Soil conservation practices were combined with production controls in the Soil Conservation and Domestic Allotment Act of 1936 in hopes that the U.S. Supreme Court would not find that combination unconstitutional, as it had the combination of production controls and a processing tax. Under this format, farmers were rewarded for voluntarily shifting production from the production of soil-depleting crops to the production of soil-conserving grasses and legumes. Many soil-depleting crops such as wheat and feed grains were in excess supply at this time. In fact, "soil depleting" crops were almost defined as those in surplus. The Supreme Court did not disturb this policy combination and it was employed in subsequent legislation. A stated goal of income parity for farmers was emphasized in this act. Income parity was defined as the ratio of purchasing power of the net income per person on farms to that of income per person not on farms which prevailed during the August 1909 to July 1914 period.[11] The base period used offered a very favorable standard to farmers. In operation, price parity was the concept employed. Drought adequately controlled grain production in 1936, and in absence of drought in 1937, the program did not give

[11]Tweeten, p. 303.

adequate control.

The components of the Agricultural Adjustment Act of 1938 were not novel, however the combination of provisions employed was unique, and became the pattern for subsequent legislation. Price supporting loans, conservation payments, parity payments, export subsidies, and federal crop insurance were combined to support farm income. As a condition for receiving price support loans, conservation payments, and parity payments, complying farmers had to control production by planting within acreage allotments or removing given acreages from the production of soil-depleting crops. A more restrictive control method was introduced for the first time in this act with the employment of marketing quotas for crops such as corn, cotton, and wheat. Marketing quotas were not to be enforced unless surpluses became great, and then only after farmer approval by two-thirds affirmative vote on the question in a referendum. If approval was not granted in such a referendum vote, no farm program for that given commodity would operate during the ensuing year.[12]

Nonrecourse loans were employed as a means of supporting prices of commodities. Such loans were made available to farmers whenever prices of commodities such as corn or wheat fell below 52 percent of parity price. The price of wheat did fall to less than 52 percent of

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[12] Hadwiger, p. 153.

parity during the first year of the program, and the loan rate was in effect acting as a price support from the beginning of the program.[13] The loan rate for certain "basic" crops (corn, cotton, and wheat) was adjusted by the Secretary of Agriculture at levels between 52 and 75 percent of parity price. These support levels on the basic crops were mandatory. The Commodity Credit Corporation was also authorized to support prices of virtually any other commodity. These commodities were called "permissive" commodities, and the support was not mandatory. Price supports for barley were initiated in 1940 under this provision. The nonrecourse loan served as a mechanism for holding crops off the market during periods of market surplus, and as the primary method for establishing and maintaining an "ever-normal granary." The objective of the "ever-normal granary" was to assure adequate food and feed supplies during poor crop years, and to provide an outlet for surpluses during good crop years to prevent large market price declines.

The Secretary of Agriculture was instructed by the Agricultural Adjustment Act of 1938 to make parity payments to producers of wheat, corn, and other "basic" crops, providing returns to these producers as nearly equal to parity prices as the available public funds would

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[13] Ibid., p. 167.

permit. The base period for parity price calculations was August 1909-July 1914. Parity payments were to be made on a normal production figure determined from a reported history of production per acre in prior years.

Estimates of the effects of policies of the Agricultural Adjustment Act indicate that acreages of wheat and other soil-depleting crops would have been as much as 30 million acres greater per year in the U.S. in the absence of existing controls. The reduction of wheat acres due to commodity program production controls was estimated to be 18 million acres per year between 1939 and 1941, and an acreage even greater than that in 1942. Wheat price studies have indicated that during the period from 1938-1942, wheat prices could have been as much as 50 percent lower than the prices that actually existed had price support programs not been in effect.[14]

A program of export subsidies as provided for in the Agricultural Adjustment Act was announced in 1938 whereby the Federal Surplus Commodity Corporation purchased wheat on the open market and sold it to exporters at a price enabling them to sell abroad. Foreign sales of wheat amounting to 94 million bushels during the 1938-1939 marketing year were assisted by the Federal Export Program in this manner. Due to the war, foreign sales decreased in

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[14] Ibid., pp. 160-161.

following years, and by 1942 a wheat storage crisis had developed. To alleviate the storage problem, wheat was channeled into alternative uses such as livestock feed and grain alcohol production. Subsidies were used to facilitate domestic sales of surplus wheat stocks. Other agricultural commodities were similarly disposed of domestically with the aid of subsidies.

During active involvement of the U.S. in World War II, emphasis of agricultural policy changed from production controls to production encouragement. High price guarantees in the form of price support loans at price levels ranging between 85 and 90 percent of parity price were common during the war. Surpluses gained before the war changed from burdens to blessings, and benefits from conservation practices were reaped in the form of increased production during the war. Nonbasic commodities, commodities other than corn, cotton, rice, wheat, and tobacco, were included in price support programs via the Steagall Amendment in 1941 at support levels equal to 85 percent of parity price. The Secretary of Agriculture was empowered to include these nonbasic commodities in price support programs if he found it necessary to increase their production. The minimum rate of support for the nonbasic commodities was raised to 90 percent of parity by the Stabilization Act of 1942. This act also extended price supports for both basic and non-basic commodities at 90 percent of parity for a length of time extending two years after the end of the war. The extension of price supports at such a high level past the end of the war was in anticipation of post-war relief requirements, and to show farmers that increased wartime agricultural production would not be rewarded with an instant production adjustment due to falling prices. The post-war price supports provided for in the Stabilization Act of 1942 were to be available only to those farmers who complied with acreage or marketing quotas that had been announced by the Secretary of Agriculture and approved by the growers.

Due to the three-year food crisis in Europe following World War II, the United States was able to export just over one billion bushels of wheat during that period. Production of wheat was expanded in the U.S. as much as possible, and U.S. officials would have preferred to export even greater quantities if such supplies had been available. Coarse grains such as corn were shipped from the U.S. to be used as food abroad. Surpluses of farm commodities were replaced by a severe scarcity situation, and this atmosphere paved the way for commodity legislation in 1948 that was quite favorable for farmers.

Price supports for basic commodities were supposed to drop back to the range of 52 to 75 percent of parity after December 31, 1948, due to the termination of the Stabilization Act. However the Agricultural Act of 1948 was approved and mandatory price supports for basic crops at 90 percent of parity were established for crop year 1949. Price supports of other commodities such as barley were authorized "at levels in a fair relationship" with prices of the basic commodities.[15] These price supports were again facilitated through price support loans. This law also provided for a revised method of making parity calculations in the future. Beginning January 1, 1950, parity prices for individual crops were to be computed so as to take into consideration both the 1910 to 1914 base period, and average prices for the previous ten years. A transitional parity scheme was devised to limit the drop from old to new parity to steps of not more than five percent of old parity per year.

The Agricultural Act of 1949 provided for price supports for the basic crops at 90 percent of parity for 1950, 80 percent of parity for 1951 (for crops with allotments or marketing quotas), and 75-90 percent of parity after 1951.[16] However, from 1949 to 1954 price supports for basic crops and "permissive" crops such as barley remained at the 90 percent of parity level. During this period the effective parity prices on basic crops was the old,

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[15] U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, Commodity Programs and Related Legislation through the Years, BI No. 11 (1975), p. 4.

[16] Ibid.

higher parity calculation, or the higher of the two parity measures. Price supports were continued in 1955 for basic crops at a level within the flexible 82.5 to 90 percent of parity range. Support levels dropped in 1956 and thereafter to the 75 to 90 percent of parity range.

Acreage controls and marketing quotas were imposed in 1954 for the first time since World War II. It was expected that lower price supports in the years 1955 and 1956 would reduce production of wheat and feed grains; however even with the subsequent acreage controls and marketing quotas, surpluses mounted. The Soil Bank Program established by the Agricultural Act of 1956 was designed as a program to counteract surpluses of farm commodities. The Acreage Reserve provision of the Soil Bank Program allowed payments for farmers to reduce plantings of allotment crops, wheat, cotton, corn, tobacco, peanuts, and rice. The other major provision of the Soil Bank Program, the Conservation Reserve, was a general cropland retirement program which allowed payment to farmers for diversion of part or all of their cropland to soil-conserving uses. The Soil Bank Program was enacted in addition to the existing price support and allotment program, and in practice, participation in the Soil Bank was not a necessary condition for receiving price supports. In the case of corn, producing within allotments was not a necessary condition for Soil Bank participation. Drought conditions prevailed in 1956, and many of the acres participating in the Acreage Reserve Program were acres on which production had already failed due to natural causes. In this respect, the Soil Bank Program was a vehicle for relief rather than just a means of controlling production. The dual objectives of drought relief and production control persisted in the 1957 Acreage Reserve Program, with most emphasis on relief goals. Reductions in wheat and feed grain acreages were accomplished, however, at an extremely high cost. In 1957 reductions in wheat production, costing $230 million, were estimated at 175 million bushels.[17] Prospects of better growing conditions for wheat greatly reduced participation in the wheat Acreage Reserve Program in 1958. Given the price support and allotment program, farmers simply found it more profitable not to commit wheat acres to the Acreage Reserve Program. From the producer's standpoint, the Acreage Reserve Program was more a drought relief program than an acreage control program. Amid speculations that appropriations for a 1959 acreage reserve program could not be obtained from Congress because of the program's record of ineffective production controls, the acreage reserve concept was phased out. Funds were instead increased for the longer term Conservation Reserve Program. Shepherd claims that Conservation Reserve rental rates overpaid the poor land, relative

[17] Hadwiger, p. 219.

to the good land, and the percentage effect of the program on production was only one-half or one-third as great as the percentage reduction in acres.[18]

The corn farmers' referendum of 1958 terminated corn allotments for the following years with the condition that price supports at 90 percent of the average price of the preceding three years be maintained. The status of barley changed from that of the "permissive" price support category to the nonbasic category with the stipulation that price supports be made available for barley "at such level of its parity price as the Secretary of Agriculture determined to be fair and reasonable in relation to the level of support made available for corn.[19] Because price support for corn was mandatory, price support for barley was also mandatory.

Tweeten refers to the Benson programs of the 1950's as an unworkable combination of price supports with ineffective production controls at a time when technological revolution had struck agriculture full force. At the end of the 1950's, carry-over stocks of wheat had reached 1.4 billion bushels and carry-over stocks of

[18]Shepherd, p. 45.

[19]USDA, ASCS, Commodity Programs, p. 8.

corn had reached 2.0 billion bushels.[20] Production controls had indeed failed.

The emergency Feed Grain Act of 1961 established the basic form of feed grain program for the 1960's. The program created by this act was voluntary, offering producers generous rewards for participation. The dominant functional element of this act was an acreage diversion program for corn and grain sorghums under which payments were made to producers who diverted acreage from the production of these feed grains to conserving uses. Producers who complied with this program qualified for price supports at 74 percent of parity, and diversion payments for those acres diverted from production. No price supports were offered to producers who did not comply with the program at the minimum level of participation. Higher payment rates were offered to producers who chose to divert acreages larger than the minimum qualifying level. This program indirectly authorized a higher price support level for barley because support rates for barley were tied to the level of support made available for corn. The feed grains program for crop year 1962, approved as the Agricultural Act of 1961, continued the policies employed in 1961 and included barley as a diverted acre crop.

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[20] Tweeten, p. 309.

Emergency wheat programs were enacted in 1962 and 1963 which extended acreage diversion provisions to wheat. The primary objective of these programs was to reduce wheat production below the 55 million acre national wheat allotment by approximately ten percent. Price supports for producers were made dependent upon compliance with the wheat acreage diversion program. Price supports during these years were maintained within the 75 to 90 percent of parity range. The acreage allotment and marketing quota system originated in 1954 , continued through 1963.

The feed grains programs through 1970 remained basically as extensions of the emergency feed grain program of 1961, employing acreage diversions with generous rewards for participation.

The wheat program for 1964 was basically a two-price plan. Complying producers were required to divert land from wheat production to soil-conserving uses. Diversion payments were made on diverted acreage, and complying producers received price supports in the form of both domestic certificates and export certificates. This program was voluntary; however producers who did not comply received no certificates and no program benefits. Programs similar to the 1964 Wheat-Cotton Act continued throughout the 1960's, with acreage diversion and marketing certificates remaining as the primary policy tools for the wheat sector.

The voluntary feed grain program established under the Agricultural Act of 1970 was a set-aside program, under which participating farmers were required to set aside feed grain acreage or other cropland in order to be eligible for price support loans and set-aside payments. The set-aside provision of this program functioned similarly to the diversion provision of the 1960's programs.

A set-aside program was also established for the wheat sector under the Agricultural Act of 1970. Under this program producers were required to set aside given acreages from the production of wheat or other substitute crops to qualify for price support loans, certificates, and set-aside payments. For the 1971 to 1973 crop years, marketing quotas and acreage allotments were suspended.

The 1961 and 1962 feed grains and wheat programs were quite effective in reducing both acreages and total production of these grains. Feed grains acreage reduction in 1961 for the country as a whole was about 13 percent, and the reduction in feed grains production was about 10 percent.[21] The difference between the reductions in acreage and production is due to the fact that participants removed their poorer acres from production and applied more variable inputs to the remaining grain acres. Also, nonparticipants in the program tended to increase their production. When examining the

[21] Shepherd, pp. 49-51.

Conservation Reserve program of 1960 for these effects, Shepherd found that eight percent of the total cropland was removed from production, and 4.5 percent of the total value of all 1960 crops could have been produced on this land removed from production.[22]

Whether measuring acres removed from production, or percent of total farm product eliminated, the feed grain and wheat programs of the 1960's appear to have been more effective than the Conservation Reserve program. Studies also indicate that the feed grain and wheat programs of the 1960's were more costly to the government, both in an absolute sense, and when measured by the standard of the reduction in value of crops produced per dollar of rental payment. Rental payments under the feed grain and wheat programs of the 1960's tended to be much higher than for the Conservation Reserve program, and the range of rental rates accomodating differing productivity levels of land was about twice as great for the programs of the 1960's.[23]

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[22] Ibid., p. 45.

[23] Ibid., p. 49.

Chapter 3

THEORETICAL CONSIDERATIONS

Theory of Supply

The theory of supply is a logical development from the theory of the firm. A firm is a technical unit in which single or multiple commodities are produced. Inherent in this technical unit is an aggregation of scarce resources for which economic returns exist. The firm is assumed to maximize profits via the postulate of rationality. Profits are defined as the difference between revenue from the sale of outputs and the costs of all inputs. The determination of optimum profits is based on a technical production function and given sets of factor and product prices. These sets of prices are determined by the supply functions of the factor markets and the demand functions of the product markets respectively.

The production function is a purely physical input-output relationship relating physical units of inputs to physical units of output. It represents the set of technical rules reflecting the "state of the arts" which specifically quantify the transformation of inputs into outputs. The concept of the production function is general, as a specific production function may be given by a single point, a single continuous function, a single discontinuous function, or a system of equations.[24] Production functions given by a single continuous function with continuous first- and second-order partial derivatives will be discussed.

The production process takes place over time, and both input and output levels are measured as flows over time. The relevant time period for a short-run production function is such that it is sufficiently short to prevent changing technology from altering its shap, sufficiently short to prevent the entrepreneur from altering the level of employment of certain inputs (plant, equipment, technology), yet sufficiently long enough to allow the completion of the production process. Fixed and variable inputs are defined relative to the time frame. Levels of usage of fixed inputs cannot be altered in the short-run, whereas levels of usage of variable inputs are totally variable within this time frame. By extending the length of the planning period, more and more inputs become variable; in the long run, all inputs become variable. Given the production functions of the firms of an industry, the factor supply functions facing the firms in the input market, and the demand functions facing the firms in the product market, cost functions and equilibrium output relevant to the industry firms can be calculated.

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[24] James M. Henderson and Richard E. Quandt, Microeconomic Theory: A Mathematical Approach, (New York: McGraw-Hill Book Co., 1971), p. 52.

Given the level of technology and fixed factors of production, different levels of production based on specific amounts of variable factors can be graphically represented on an isoquant map, figure 3.1. In the case of a continuous production function with two variable inputs, positive levels of the variable inputs x_1 and x_2 are measured on the X_1 and X_2 axes. The positive quandrant of the X_1X_2 plane represents input space and every point thereof represents a specific input combination. Each isoquant q^i represents different combinations

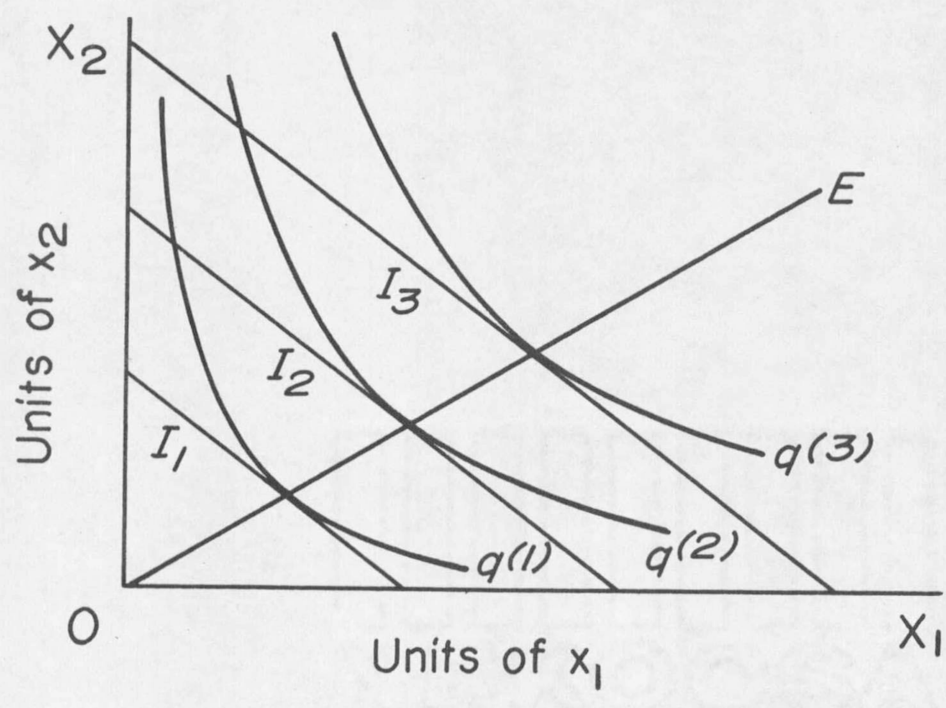

Figure 3.1 Isoquant Map

of variable inputs x_1 and x_2 that yield the same level of output. The slope of the tangent to a point on an isoquant is the rate at which x_1 must be substituted for x_2 (or x_2 for x_1) in order to maintain the corresponding output level. The negative of the slope is defined as the rate of technical substitution (RTS).[25] Higher levels of total product are represented by isoquants located farther from the origin.

First order conditions for both constrained output maximization and constrained cost minimization can be represented on the isoquant map with the addition of another construct, the isocost line. An isocost line is defined as the locus of input combinations that may be purchased for a specified total cost. The X_1-intercept of the isocost line I_1 gives the amount of x_1 that can be purchased for total cost C_1: the X_2-intercept gives the amount of x_2 that can be purchased for C_1 and input combinations of x_1 and x_2 along I_1 also cost C_1. The slope of the isocost line equals the negative of the factor price ratio. Perfect competition in the input market is assumed in this analysis.

If the relevant family of isoquants is convex to the origin, every point of tangency between an isoquant and an isocost line is the solution of both a constrained output maximization problem and

[25] Ibid., p. 59.

a constrained cost minimization problem. The locus of these tangency points is defined as the expansion path of the firm under consideration. As only least cost input combinations for successively larger levels of output lie on the expansion path (moving outward from the origin on OE), a rational entrepreneur will employ only the input combinations lying on the expansion path. The assumption of perfect competition in both the factor and product markets is required for the preceding analysis. Recalling the significance of the slopes of isoquants and isocost lines, in equilibrium production will occur on the expansion path where the rate of technical substitution between any two variable inputs is equal to the ratio of their prices.

Graphically, second-order conditions for constrained output maximization or constrained cost minimization require that any isoquant tangent to an isocost line satisfying first-order conditions must be convex to the origin. This requires that first-order conditions are obtained at the highest achievable output level. For isoquants concave to the origin, first-order conditions would indicate that the solution is one of output minimization or cost maximization.

A continuous short run production function of a single firm can be represented by:

$$Q = f(X_1, X_2, \ldots, X_n + B) \tag{3.1}$$

where,

Q is the quantity of output produced,

X_i, $i = 1,2,\ldots,n$, are the quantities of variable inputs employed, and

B is the quantity of fixed inputs employed in production. In this production function, B is treated as a parameter and Q is a function of the variable inputs X_i.

The total cost function associated with the above production function can be expressed as:

$$C = r_1X_1 + r_2X_2 + \ldots + r_nX_n + b \qquad (3.2)$$

where,

C is the total cost of production,

r_i, $i = 1,2,\ldots,n$, and

b is the total fixed cost.

Generally, the profit function of a firm selling in a perfectly competitive market can be expressed as:

$$\pi = pQ-C \qquad (3.3)$$

where,

π is the difference between revenue from the sale of outputs and the costs of all inputs, or profit,

p is the fixed unit price of output,

Q is the quantity of output marketed, and

C is the total cost.

More specifically, the profit function can be generated by substitution from (2.1) and (2.2) as:

$$\pi = pf(X_1, X_2, \ldots, X_n + B) - \sum_{i=1}^{n} r_i X_i - b \qquad (3.4)$$

In this functional form it can be seen that profit is a function of x_i, hence π is maximized with respect to these variables.

One method of examining conditions associated with optimizing behavior is to examine the maximization of output subject to a cost constraint. Forming the Lagrangian function,

$$V = f(X_1, X_2, \ldots, X_n + B) + \mu(C - \sum_{i=1}^{n} r_i x_i - b)_1 \qquad (3.5)$$

first-order conditions can be met by forming the partial derivative of V with respect to x_i and (an undetermined Lagrangian multiplier), setting these partial derivatives equal to zero, and solving for f_1/f_2.

$$\begin{aligned} \partial V/\partial x_1 &= f_1 - \mu r_1 = 0 \\ \partial V/\partial x_2 &= f_2 - \mu r_2 = 0 \\ \partial V/\partial \mu &= C - \sum_{i=1}^{n} r_i x_i - b = 0 \\ \mu &= f_1/f_2 = r_1/r_2 \end{aligned} \qquad (3.6)$$

First-order conditions may be expressed as the equality of the ratio of the marginal products of x_1 and x_2 to the ratio of their respective prices, or the equality of the rate of technical substitution and the input price ratio. It will be recalled that the rate of technical substitution is equal to the input price ratio.

Second-order conditions for constrained output maximization are met if the relevant bordered Hessian determinant is positive. This ensures that the rate of change of slope of a tangent to an isoquant is positive, $\partial^2 x_2/\partial x_1^2 > 0$, or that the isoquants are convex to the origin. For the case of constrained cost minimization, first- and second-order conditions are identical with those of constrained output maximization.

Profit considerations are assumed to be primary factors determining the organization of production of the firm. First-order conditions for profit maximization are met by partially differentiating (2.4) with respect to x_i, setting these partials equal to zero and solving. The partial derivatives of the production function with respect to the variable inputs are the marginal products of the variable inputs. First-order conditions for profit maximization require that each variable input be employed up to a point at which the value of its marginal product (VMP) equals its price. Positive increments to profit can be obtained as long as additions to revenue from the employment of variable inputs exceed the cost of these inputs. The combination of inputs yielding maximum profit can be found on the expansion path.

Second-order conditions for profit maximization are met if the principle minors of the relevant Hessian determinant alternate in sign:

$$\partial^2\pi/\partial x_1{}^2 = pf_{11}<0 \quad , \quad \partial^2\pi/\partial x_2{}^2 = pf_{xx}<0 \qquad (3.7)$$

and

$$\begin{vmatrix} \partial^2\pi/\partial x_1{}^2 & \partial^2\pi/\partial x_1x_2 \\ \partial^2\pi/\partial x_2x_1 & \partial^2\pi/\partial x_2{}^2 \end{vmatrix} = P^2 \begin{vmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{vmatrix} > 0 \qquad (3.8)$$

Inequality (3.7) indicates that for second-order conditions of profit maximization to be met, profit must be decreasing with greater levels of usage of variable inputs x_1 or x_2. Inequality (3.8) shows that for additional usage of both variable inputs x_1 and x_2 profit is also decreasing. Alternatively, (3.7) and (3.8) require that the production function be strictly concave in the region of a point at which first-order conditions are met, with x_1 and $x_2 \geq 0$ if such a point exists. If the production function possesses no region which is strictly concave, and at which levels of inputs and output are nonnegative, competitive profit-maximizing solutions as described here cannot be obtained.

Assuming rational behavior of the entrepreneur and optimal input combinations in production, the analysis of profit maximization can be pursued in terms of revenues and costs expressed as functions of output. The short-run supply function of the competitive firm can be developed from the production function (3.1), the total cost function (3.2), and the expansion path function. This system of three equations can be reduced to a single equation stating cost as an explicit function of the level of output plus the cost of fixed factors.

$$C = \phi(q) + b \qquad (3.10)$$

Combinations of output levels and their corresponding costs can be obtained by selecting various points on the expansion path, substituting the corresponding input level values into the production function to obtain the output level, multiplying the input level values by the given input prices to obtain total variable costs, and adding fixed costs. This procedure will give the minimum cost of supplying any output level. The supply schedule is that part of the marginal cost function which is greater than average variable costs:

$$MC = dC/dq = \phi'(q) \qquad (3.11)$$

$$AVC = \phi(q)/q \qquad (3.12)$$

Retaining the assumptions of perfect competition in the factor and product markets and profit maximizing behavior, revenues and profit are a function of output:

$$\pi = pq - \phi(q) - b \qquad (3.13)$$

First-order conditions for profit maximizations are obtained by partially differentiating the profit function with respect to q and setting the derivative equal to zero,

$$d\pi/dq = p - \phi'(q) = 0, \qquad p = \phi'(q) \qquad (3.14)$$

This states that to maximize profits marginal cost must equal the given market price for the output. In the relevant range of production, if market price is greater than marginal cost, the entrepreneur can increase profit by expanding output; conversely, if market price is less than marginal cost, profit can be increased or losses can be reduced by decreasing output. The second-order condition for profit maximization states that

$$d^2C/dq^2 = d^2C/dq^2 < 0, \text{ or } d^2C/dq^2 > 0 \qquad (3.15)$$

This means that marginal cost must be increasing at the level of output where profit is maximized. If marginal cost were in fact decreasing where marginal cost equals market price, profit minimization would occur.

Fixed costs do not enter in the production decision process in the short-run. Discontinuing production and accepting a loss equal to total fixed cost would occur if the loss accepted from producing zero output would be less than the loss sustained from producing any positive output level.

In the short-run certain scarce inputs such as management, plant and equipment are assumed fixed. Assuming competitive conditions in the factor and product markets and firm profit maximizing behavior, all inputs become variable in the long-run and the entrepreneur can alter management, plant and equipment, such that the lowest unit cost of production is attained.

The long-run supply function is developed by incorporating all factors as variable in the production function, the total cost function, and the expansion path function. Representing plant, equipment, and technology (all factors of production assumed fixed in the short run) by k, this gives:

$$q = f(x_1, x_2, K_1 \ . \ . \ . \ x_n),$$
$$C = r_1x_1 + r_2x_2 + \psi(K) + . \ . \ . + r_nx_n, \qquad (3.16)$$
$$0 = g(x_1, x_2, K, x_n).$$

Reducing this system of equations, total cost can be expressed as a function of plant size and output level.

$$C = \emptyset(q,K) + \psi(K). \qquad (3.17)$$

For any given output level, the entrepreneur can calculate the total cost for each value of k and select the plant size for which total cost is a minimum. This point will lie on the long-run total cost curve. Assuming k continuously variable, the long-run total cost curve is the envelope of the infinite number of short-run total cost curves, or the locus of all minimum cost points of the short-run cost curves, with one point of the long-run total cost curve in common with one point of each of the short-run curves.

In the long-run, first- and second-order conditions for profit maximization are obtained by differentiation of the profit function, where profit during a given period is the difference between revenue and cost, with plant size variable:

$\pi = Pq - \Phi(q)$

First- and second-order conditions state that long-run marginal cost must equal market price at the point of profit maximizing output, and that the marginal cost function must be increasing at this output level.

Long-run total cost and long-run average cost are the envelope curves of the short-run total cost curves and short-run average cost curves respectively. An analogous situation with respect to long-run and short-run marginal cost curves does not hold. Portions of a short-run marginal cost curve may lie below the long-run marginal cost curve for a given output, but the long-run marginal cost curve is defined as the locus of points on the short-run marginal cost curves where plant size is optimal for the given output. The long-run supply curve of the competitive industry, however, will coincide with the long-run average cost curve, and may exhibit the existence of either external economies or diseconomies of scale. The tendency of long run supply to approximate the curve of average costs for the industry results from assumptions of competitive institutions, such as free-entry and free-exit and profit maximizing behavior on behalf of individual firms, leading to long-run zero profit equilibrium common to the competitive industry.

The classical supply function of the individual firm expresses the functional relationship between quantity produced of a given commodity and its own product price, with input prices and all other supply shifters held constant. Immediate adjustment of the dependent variable S_i (supply of a given commodity of the ith firm) to changes in the independent variables and parameters of the supply function is implied from the assumptions of the perfectly competitive market structure of the factor and product markets. Implicit in the concept of the supply function is the notion that one or more input factors may be varied and that these factors are substitutable in the production process. The supply function is also reversible in the sense that inputs can be added or taken away from production.

The supply function of an agricultural commodity (e.g., wheat) exemplifies a greatly inhibited instantaneous adjustment of the dependent variable, supply of wheat, to changes in the independent variables of the supply function. The primary factors inhibiting this adjustment are physical or biological in nature, lack of information, traditional production practices, and cultural aspects of agricultural producers.

Product price uncertainty is another important element inhibiting production adjustments in agriculture. The farmer plants and takes a chance. The risk attributed to product price uncertainty involves a cost which can be included in the cost structure of the firm. As the risk varies directly with the quantity of commodity produced, the cost attached is a variable cost which has the effect of raising the marginal cost and contracting the supply function for the commodity in question. Similarly, given a change in relative prices of commodities, price uncertainty would inhibit a full production adjustment by farmers. Price uncertainty would affect the longer-run production adjustment of farmers to a change in relative commodity prices by diminishing the adoption of costly innovations in production.

The positively sloped commodity supply function (e.g., wheat supply function) is assumed to reflect the movement of factors into production of this commodity, given an increase in relative price of wheat. The slope (elasticity) of the commodity supply function will depend on the production time period and the existence, extent and closeness of production alternatives. If the length of run is long and the production alternatives are numerous and quite close, a relatively small increase in the price of wheat would be associated with a relatively large increase in the quantity produced. It is characteristic in most agricultural production for certain primary factors of production to remain fixed in the short run. This resource fixity imposes a constraint on the technical substitution possibilities of resources among enterprises, within and between farm firms. The factors which tend to get fixed in production are: (1) labor, in the form of the family labor force; (2) the total number of acres per farm; and, (3) the total amount and form of heavy machinery and equipment. The elasticities of supply of farm commodities such as wheat and barley tend to be quite low and considerable variation in relative supply elasticities between different commodities has been found. Past studies have estimated the supply elasticities of wheat and barley to be inelastic, ranging between zero and one.

Changing the unit of inquiry from that of the commodity to that of the firm, the relevant supply function is a supply function for aggregate output of the farm firm, since the typical farm firm is a multiple enterprise. Most economists would agree that this supply function of the farm firm is severely inelastic. Fixity of resources such as labor, land, and many forms of capital in the short-run is the primary determining cause of this inelasticity. If the firm is a "going concern," the costs of these inputs do not vary relative to usage levels, and they are usually fully employed. Given rising farm commodity prices, land and labor resources cannot be increased by individual operators bidding against one another; given falling farm commodity prices, farm labor, land, and sunk capital lack employment alternatives. Returns to these resources fall along with product prices and they tend to remain employed on the same farm units. The inelastic nature of the short-run aggregate output supply function for the farm firm can also be attributed to the lack of flow of land and labor resources across the farm-nonfarm line in response to changing resource prices. The tendency of farmers to view farming as a way of life more than as a profit maximizing business, thereby not responding as readily to economic stimuli, tends to diminish the elasticity of the supply function for aggregate output of the farm firm. Given a change in relative prices of farm commodities, a substantial change in composition of the aggregate output of the individual farm firm would be expected.

Supply Response

Supply response, or a response relation in general, is a term used in describing how the quantity of a commodity offered for sale varies with changes in the relative price of the commodity. The term supply (or output) response is a more general concept than is supply function, and it is inclusive of the concept of net supply relation.

The short-run aggregate supply curve for a given commodity states the quantity of this commodity the firms of the industry will produce as a function of market price. An individual firm's short-run supply curve is identical with that portion of its short-run marginal cost curve which lies above its average variable cost curve. The aggregate short-run supply function for a given commodity is obtained by summing the individual supply functions of all the firms of the industry. Output levels (supply levels) can be varied in the short-run in response to changes in market price of the commodity in question, but the level of employment of capital items such as equipment, land, and management cannot be varied.

The firm's long-run supply curve is identical with that portion of its long-run marginal cost function for which marginal cost exceeds average cost. Hence the firm's long-run supply curve states the quantity of a given commodity it will produce as a function of market price, with all inputs variable. The long-run aggregate supply function of the industry is a positively sloped function under the assumption of increasing costs.[26]

Heady describes the response relation as a mongrel relation.[27] A response relation involves both movements along a supply curve and shifts in supply.[28] Given an increase in the market price of wheat, new techniques of production are likely to be introduced. A price increase could cause farmers to increase output along an existing static supply curve, and it could lead to a shift to a new supply curve. The resulting increase in output would then be greater

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[26] Ibid., p. 111

[27] Willard W. Cochrane, "Conceptualizing the Supply Relation in Agriculture," Journal of Farm Economics 37 (1955): 1161-1176.

[28] William G. Tomek and Kenneth L. Robinson, Agricultural Report Prices, (Ithaca: Cornell University Press, 1972), pp. 71-73.

than the increase anticipated if a forecast were based solely on the static concept of supply.

A response relation is concerned with the output response to a price change and is concerned with the shifters of supply, with time not held constant. The classical supply function is reversible, but the response relation is not reversible because of shifts in variables and parameters. A response relation generally traces out one path for an increase in relative price and a different path for a decrease.

Technology, or the changes in technology over time, is an important variable held constant in a supply function, but allowed to vary in a response relation. Technology is significant in lending the nonreversible nature to the response relation, as farmers would not tend to give up a technological advance once adopted.

Given a positive relative price change of an agricultural commodity, the corresponding supply response relation would be more elastic than the corresponding supply relation. The quantity of this commodity offered for sale would increase in response to the increasing price as a result of several processes working together. They include resources attracted to the production of this commodity from less profitable farm enterprises, changes in input costs, changes in prices of substitutes, and the adoption of new technology.

Given a declining price, the response relation would describe declining quantities offered for sale, however, the absolute value of the rate of decrease in production would be less than the absolute value of the rate of increase during the increasing price phase. Given falling relative commodity, prices resources such as land and labor can be shifted into production of other commodities, however, technological advances will not be given up easily, especially if these advances have led to lower unit costs of production. This implies that agricultural producers will produce and sell, at some particular price, a larger quantity in an environment of declining prices than they would have produced and sold at that same particular price in the preceding increasing price phase.

The coneept of supply (or output) response describes how output, or actual quantity supplied varies with price and the supply shifters over some period of time. In terms of real-world happenings, the response relation is a useful concept.

Chapter 4

ECONOMETRIC THEORY AND STATISTICAL CONSIDERATIONS

Price and Policy Variables

The supply models developed in this thesis are acreage responses for Montana wheat and barley, with the dependent variable specified as "acreage planted" of the respective crops. The relationship between "acreage planted" and "acreage harvested" of wheat and barley was originally assumed to be very close. Coefficients of correlation for acreage planted and acreage harvested of wheat and barley in Montana are .87 and .96, respectively. It was assumed the existing variation between these two data series was caused by random environmental factors, with no systematic economic relationship generating the variation.

Policies of recent past farm legislation based on production control and soil conservation objectives have likely increased yields of many crops. In referring to earlier studies, Tweeten claims that acreage allotments have contributed to higher yields.[29] Shepherd asserts that soil conservation measures have increased both acreage

[29] Tweeten, p. 315.

and yields of surplus crops.[30] This thesis does not address the analysis of total production or production rates of farm commodities. Acres of the input land is the variable under investigation.

The general functional relationship serving as a basis of this investigation can be expressed as:

$$A_i = f(P_i, G, R) \tag{4.1}$$

where,

A_i represents annual Montana acres of the ith crop planted,

P_i represents all relevant open-market forces which are assumed to affect all planting decisions in the State of Montana. Of primary importance here are present and recent past market prices of the crop in question, market prices of substitute commodities in production, and livestock prices. P_i could also represent other productive inputs such as heavy machinery, fertilizer, and interest rates.

G represents all relevant Government program policies which affect the acreage planted of different Montana crops. Nonrecourse loan rates, direct support payments, payments for reducing planted acreages of different crops, and various forms of acreage restrictions are the most important elements of this category.

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[30] Shepherd, p. 205.

R represents all other supply determining factors: Unspecified economic factors, noneconomic factors, and random effects. Weather factors, plant diseases, and elements such as weed and insect problems would be included here. Also, exogenous factors which could significantly influence producer expectations and individual farm cropping patterns would be contained by R.

Many of the elements properly included in either P_i, G, or R above may not be considered measurable due to data considerations. However, the factors considered most important in determining the acreage planted of a given Montana crop can be included in one of the three categories given above.

In analyzing farm commodity supply relationships, lagged market prices are generally assumed to be the relevant supply-inducing variables. The imposition of Government support prices into an otherwise free market can raise serious questions about this approach. Houck and Ryan found that the presence of Government price supports made the net relation between lagged market prices and acreage difficult to isolate.[31] Past research by the same investigators and others indicated that generally greater acreage responsiveness to lagged market prices than to current price supports

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[31] Mary E. Ryan and James P. Houck, "Supply Analysis for Corn in the United States: The Impact of Changing Government Programs," American Journal of Agricultural Economics 54 (May 1972): pp. 184-191,

occurred when the relevant past market prices exceeded the corresponding support prices. Given a situation where the price support level of a given commodity exceeded the corresponding free market price, a "weighted support price" variable was found to better explain variations in acreage planted of that commodity than was the lagged market price.[32] Also, intercorrelation between weighted support prices and lagged market prices reduced the significance of both variables when they were used in the same regression equation.

Recent farm commodity programs pertaining to various commodities have had policies which were adjustable on an annual basis. In the past, certain specific policies have remained in effect for only one crop year; others have remained in effect for many years. In evaluating the influence of Government farm program policies on planted acreage of Montana wheat and barley, numerous policies effective for varying time periods must be generalized or reduced down to a few quantitative variables which are capable of statistical measurement and inference.

In this discussion of the influence of Government farm commodity programs on acreage planted of a given crop, it is assumed that the acreage planted of a given crop for any year is a function

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[32] Ibid.

of current Government farm program variables, past market prices of other commodities, and all other supply shifters. Given both an open-market price of a certain commodity and a program influenced price (support price), the program influenced price is assumed to be the relevant supply-inducing price. Such a relationship can be graphically represented by figure 4.1. In this relationship, acreage planted is expressed only as a function of the current support rate. Past relevant commodity prices, program policies and supply shifters are held constant. The conceptual framework of policy variables for wheat and barley are due to Ryan and Able.[33]

If the Government announced a certain support rate, PA_t, and did not make this support rate conditional upon either voluntary or mandatory production controls, the announced support rate would be viewed by producers as a simple price guarantee. In figure 4.1, it can be seen that q^o would be planted at a price support level of PA_t.

Assume that policymakers attempt to adjust annual program policies in order to elicit certain production responses from farmers, and that these policies are determinable from some optimal projected production level. Further assume that the desired acreage

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[33] Mary E. Ryan and Martin E. Abel, "Corn Acreage Respouse and the Set-Aside Program," Agricultural Economic Research 24 (October 1972): pp. 102-112.

of the crop in question is q^1 (figure 4.1). Given the supply relationship embodied in S_1, acreage level q^1 could be achieved by lowering the support rate to WS_t, assuming market price, $P_m < WS_t < PA_t$. Frequently, however, because of the effect such a price fall would have on farm income, policy-makers do not find it feasible to achieve production responses in this manner. Another method of inducing producers to reduce crop acres to the q^1 level would be to announce the support rate of PA_t, but require reductions in production equal to acreage input q^o-q^1. Reductions of crop acreages by individual farmers could be attained by requiring each farmer to reduce his acreage input by a given percentage (r) from some established historical base quantity. Such a production adjustment in the aggregate would shift the supply function from S_1 to a supply function in the region of point C. In this example, WS_t could be called the "effective support rate," with the relationship between announced support rate and effective support rate expressed by the following equation:

$$WS_t = rPA_t \tag{4.2}$$

where r is an adjustment factor reflecting the reduction in planted acreage required to attain PA_t. A price support with no planting restrictions implies r = 1.0, and as planting restrictions tighten, r would approach zero. Given a price support policy accompanied by acreage restrictions of the type discussed above, producer income protection demonstrated by the size of area Y in figure 4.1 is available to participating producers.

Another method of reducing crop acreages while maintaining farm income is for the government to make direct payments to farmers as rewards for either leaving land idle or employing it in a soil-conserving practice. Referring to figure 4.2, assume that policy-makers choose to reduce planted crop acres by magnitude q^o-q^1. In addition to the two methods described above, payments (referred to as "diversion" payments or "set-aside" payments during the 1961-1973 period) at a rate comprable to net returns from crop production, could be offered to farmers for diverting land from crop production. In past applications of this type of acreage control, program administrators have allowed varying levels of diversion, at given payment rates, from an established base acreage. Base acreages of different crops per farm were established from historical production records. Sufficient participation by farmers in such a diversion program would shift the supply relationship S_d to S_d' in figure 4.2. The relationship between the payment rate for diversion, PD_t, and the "effective diversion payment rate," WD_t, can be shown in equation 4.3:

$$WD_t = pPD_t \qquad (4.3)$$

where p is the proportion of the historical base acreage of the relevant crop eligible for diversion. The adjustment factor p

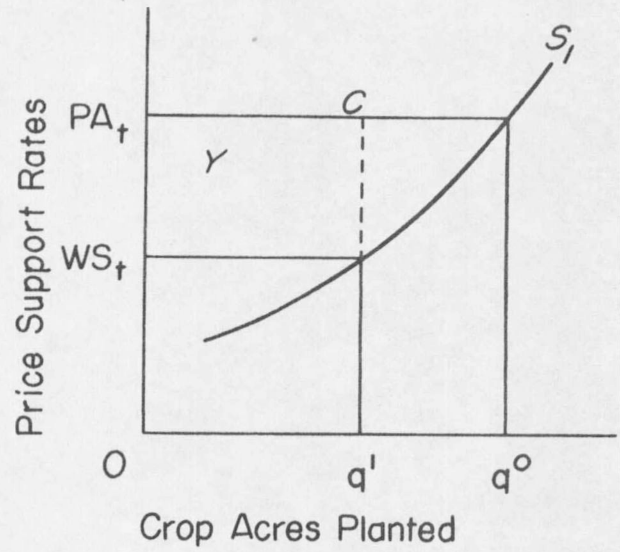

Figure 4.1 Montana crop acres planted for harvest as a function of govenment price support rates.

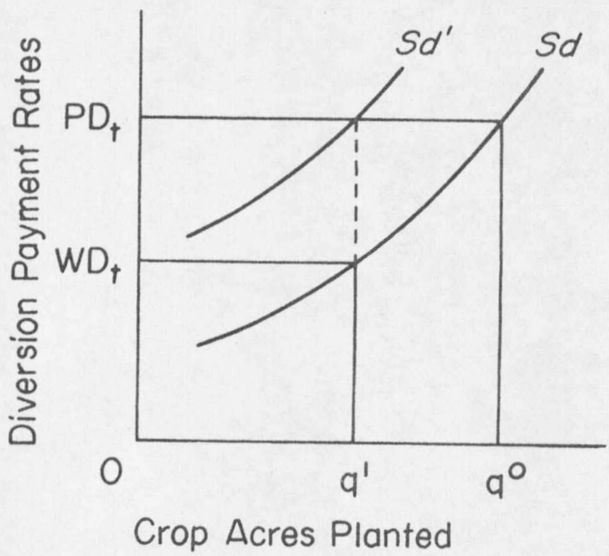

Figure 4.2 Montana crop acres planted for harvest as a function of government diversion payment rates.

ranges in value from 1.0 to zero. Given no limit on allowable diversion levels, p = 1; however p would fall very close to zero if only small percentages of given crop base acres were allowed for diversion. In figure 4.2 it can be seen that at diversion payment rate PD_t, if no restrictions were placed on the percentage of base permitted diverted, q^o would be diverted from production, holding constant all other factors. Increases in the diversion payment rate PD_t would generate increases in the amount of acreage diverted along S_d, and decreases in acreage diverted could be generated by decreases in PD_t. PD_t can be viewed as a government rental rate for land, with p representing the limit to which individual farmers can rent their base acres of different crops.

In the time period examined for this thesis, policy combinations can be represented by the variables WS_t, PA_t, WD_t, and PD_t. Considering equations 4.2 and 4.3 and figures 4.1 and 4.2, the interrelationship between the support rate variables and the diversion rate variables can be noted. Given an increase in WS_t or PA_t, thereby increasing acres planted, S_d would shift to the right. Similarly, an increase in PD_t or WD_t would tend to shift S_1 to the left.

Actual planting decisions of ag producers are influenced by such variables representing different crops and policies and their interactions. WS_t and WD_t are constructed variables, constructed from observed data of the farm programs. This approach is general, since it permits formulating WS_t and WD_t from farm programs differing considerably in basic structure. Therefore, consistent interpretation of the farm programs and identification of the components of these programs are minimal requirements in developing useful data series. Despite changes in program structure, diversion levels are expected to be represented as accurately as administrative specifications required during the active life of these programs.

The General Linear Model

Economic theory is concerned with the relationships among economic variables. Econometrics is concerned with quantifying the theoretical relations by estimating and testing the significance of the parameters involved. Economic relationships dealt with in econometrics are usually treated as stochastic. Given a relationship between X_i and Y_i, $i = 1, 2, \ldots, n$, for each set of values of X_i there is a probability distribution of values of Y_i. The following represents the classical multiple linear regression equation:

$$Y_i = b_1 + b_2X_{i2} + b_3X_{i3} + \ldots + b_kX_{ik} + \varepsilon_i, \; i = 1,2,\ldots,n. \tag{4.4}$$

where,

Y_i is the dependent variable,

X_{ij} are the explanatory or independent variables, $j = 1,2,...,k$

b_j are the unknown population parameters,

and ε_i is a random disturbance term.

The presence of a stochastic disturbance term in the equation allows Y_i to assume an array of values each with a given probability.

In a stochastic relation represented by equation 4.4, Y_i is said to be functionally dependent on X_i. This implies that for some set of values of X_i, a change in this set of values will dictate a change in the mean value of Y or a change of some characteristic of the distribution of Y. Given a change of X_i, changes of both the mean and the variance of the distribution of Y is the general case. Formalized economic theory is generally stated in deterministic form, not because stochastic influences are assumed absent, but because systematic economic influences are considered more important.

The multiple regression model is often the simplest way to describe economic relationships. The general linear model states that the value of an observable random dependent variable is a linear function of several observable independent variables and an unobservable stochastic disturbance. Linearity of the model refers to linearity in the unknown structural parameters.

In matrix notation, equation (4.4) consisting of k - 1 explanatory variables can be rewritten as

$$Y = Xb + \varepsilon \qquad (4.5)$$

where,

Y is an (n X 1) column vector of n observations of the explanatory (dependent) variable.

X is an (n X k) matrix of observations on k explanatory (independent) variables.

b is a (k X 1) column vector of unknown population parameters.

ε is an (n X 1) column vector of unobservable stochastic disturbance terms.

The following set of assumptions is required for the complete specification of the multiple regression model.

(4.a) $\varepsilon \sim N(0,\Sigma)$, where 0 is a column vector of zeros and $\sum$ is a diagonal matrix of (n x n),

(4.B) $\Sigma = \sigma^2 I_n$, where I_n is an identity matrix of order (n X n),

(4.C) The elements of the matrix X are nonstochastic with values fixed in repeated samples, and the matrix $(1/n)(X'X)$ is nonsingular and such that, for any sample size, its elements are finite.

Assumption (4.A) states that the unobservable disturbance term is normally distributed and has an expected value of zero. Assumption (4.B) indicates that each disturbance has constant unknown variance and that the disturbances are not serially correlated. Taken together, assumptions (4.A) and (4.B) imply that not only are the disturbances uncorrelated, they are statistically independent in the probability sense.[34] Assumption (4.C) indicates that the set of values of X_i is taken to be the same from sample to sample, that the values of any X_i in the sample must not all be equal to the same number, and that the values of any X_i cannot grow or decline without limit as the sample size increases. Also included in assumption (4.C) is the provision that the rank of matrix X is $k < n$ and the requirement that none of the explanatory variables be perfectly correlated with any other explanatory variable, or with any linear combination of other explanatory variables.

The above model, inclusive of the basic assumptions, describes a relationship, whereby, for every given set of explanatory variables X there exists a conditional distribution of the values of Y. The mean of the conditional distribution of Y is a linear function of the X, implying that the slopes of a linear sample regression function do not depend on the levels of the explanatory variables, and the variance of the distribution of Y is constant. Given that ε is distributed normally with variance σ^2, Y is also distributed

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[34] Jan Kmenta, Elements of Econometrics, (New York: The Macmillan Company, 1971), p. 203.

normally with variance σ^2, as Y is merely a linear function of ε.

Given a multiple regression model, the objective is generally to estimate the regression parameters in the column vector b. Employing the multiple linear regression model (4.5) including the basic assumptions (4.A)-(4.C), least squares estimation will yield estimators with all the desired properties.

Hypotheses testing and prediction are often the original motives for undertaking a statistical investigation employing least squares estimation. Statistics required for these tasks include an estimator of the variance of the disturbance term and estimates of the variances of the partial regression coefficients. The unbiased estimator of the variance of the unknown disturbance term σ^2 is given by

$$\hat{\sigma}^2 = e'e/n-k \tag{4.6}$$

where,

$e'e$ is the residual sum of squares, and

$n - k$ is the necessary degrees of freedom

and the variance of b_i is read from the main diagonal of the variance-covariance matrix of the least squares estimators of the regression slopes,

$$\hat{\text{Var}}\ \hat{b}_i = \hat{\sigma}^2(X'X)^{-1} \tag{4.7}$$

The covariances of the estimators are given by the off-diagonal terms.

Violations of the basic assumption (4.A) - (4.C) are not uncommon in least squares estimation when employing economic data. Because of the particular nature of economic relationships and the fact that economic data are collected from the real world (a non-controlled environment), violations of the basic assumptions can be expected and their impact analyzed.

The quality of an estimator is judged relative to its sample distribution properties. Only small sample properties of estimators will be discussed here. An estimator that is unbiased, efficient, and best linear unbiased, reflects all the desired small sample properties of estimators that are important and commonly mentioned i econometric work.[35] These properties are defined in terms of means and variances, and cannot be evaluated for estimators whose means and variances do not exist. Given that assumptions (4.A) - (4-C) hold, b_i, the least squares estimators are best linear unbiased estimators (BLUE), and possess all the desired small sample properties.

Statistical Considerations

Multicollinearity

Assumption (4.C) requires that none of the explanatory variables

[35]Ibid., p. 162.

be perfectly correlated with any other explanatory variables or with any linear combination of other explanatory variables.[36] Violation of this assumption would be an example of perfect multicollinearity. However, if all explanatory variables would be uncorrelated with each other, absence of multicollinearity would exist. The degree of multicollinearity is the relevant issue, not its presence or absence. Also, since multicollinearity refers to a condition of the explanatory variables that are assumed to be non-stochastic, it is a feature of the sample, not the population.[37] Multicollinearity, or rather cases of a high degree of multicollinearity are not uncommon in supply and demand work in econometrics due to the nature of economic relationships and data.

Given perfect multicollinearity, estimation of individual regression coefficients of a multiple regression model is impossible. The existence of an exact linear relation between the explanatory variables, or between one explanatory variable and a linear combination of other explanatory variables defines a situation whereby one of the columns of the (X'X) matrix is an exact linear function of one or more columns. In this situation, no

[36] Ibid., p. 380.

[37] Ibid.

solution exists since the determinant is zero.

A high degree of multicollinearity implies that the variances and covariances of the estimated regression coefficients are large. The large variances of the least squares estimators would yield estimates of the regression coefficients that are imprecise. Estimated regression coefficients can also be very sensitive to particular sets of sample data, and as Johnston notes, addition of a few more observations can sometimes produce dramatic shifts in some of the coefficients.[38] Incorrect exclusion of variables from an econometric analysis, because their estimated coefficients do not test out to be signifcantly different from zero, is a further consequence of multicollinearity.

One method of dealing with the situation of high multicollinearity is to draw information from sources outside the sample. In this way, the values of a given estimate might be inferred without using a series of data that would lead to a serious multicollinearity problem. Another way of handling this problem might be to choose only those explanatory variables of the relevant equation which are not highly correlated with each other. In this case it is possible that a given explanatory variable deemed relevant by

[38] J. Johnston, Econometric Methods, 2d ed., (New York: McGraw-Hill Book Co., 1972), p. 160.

economic theory would not be included in the analysis. A trade-off would exist between a multicollinearity problem and a model specified with less than the most theoretical desirable explanatory variables.

An often-advised remedy to the problem of high multicollinearity is the use of a new data set or increasing the number of observations. However, assuming that all of the available information about the population was employed in the original specification and estimation, the remedy advises action that should have been done anyway. Cases might exist whereby costly reformulations of original data give rise to explanatory variables that avoid the problem.

The technique of principal components is also a useful method, particularly where many independent variables exist. Usually the variation in k independent variables can be expressed in terms of r ($r < k$) independent variables. It should be kept in mind in the original specification of the model that cross-sectional data are more likely to be free of multicollinearity problems than are time series data, as many economic time series move quite closely together.

Given no exclusion of a relevant explanatory variable in the specification of a multiple regression model, a problem of high multicollinearity would not tend to bias the standard deviation of the disturbances. Multicollinearity could lead to biased regression coefficients if the large variance of a given regression coefficient reduced the statistical significance of the corresponding variable such that it was then excluded from the model. If in fact that variable had been correctly specified, the remaining coefficients would possess bias.

Transformations of original data to first differences can sometimes be used when working with time-series data to reduce the multicollinearity problem. The cost of this technique is the introduction of a degree of autoregression in the disturbances which were otherwise assumed independent.[39] Also, a priori specification of the model might suggest against the use the first difference approach.

Finally, Kmenta notes that a high degree of multicollinearity is simply a feature of the sample that contributes to the unreliability of the estimated coefficients, but is not relevant to the conclusions drawn as a result of this unreliability.[40]

Autocorrelation

Assumptions (4.A) and (4.B) imply that the stochastic disturbance occurring at one point of observation is not correlated with disturbances occurring at other points of observation. This follows from the assumption that the effect of the disturbance of one period

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[39] Kmenta, p. 390.

[40] Ibid., p. 391.

does not carry over into another period. Interpreting the stochastic disturbance term as a summary of a large number of random and independent factors that enter into the relationship under study, violations of the assumption of nonautoregression would appear more likely with time series data than with cross sectional data. Also, shorter time periods would be more likely to exhibit autoregressive disturbances than would longer time periods.

Incorrect specification of the true functional form of the economic relationship under study can lead to violation of the assumption of serially independent error terms. As Johnston notes, specifying a relation as linear between Y and X when the true relation is quadratic will give rise to a quasi-disturbance term associated with the linear relation containing a term in X^2.[41] This occurs even though the disturbance term in the true relation may be non-autocorrelated. If autoregressive elements are present in this incorrectly specified explanatory variable, the disturbance term of the linear regression equation will not satisfy basic assumptions (4.A) - (4.C) due to the presence of autoregressive elements.

Autoregressive disturbances can also be attributed to other incorrect specifications of the maintained hypothesis such as ommission of relevant economic variables or inclusion of incorrect

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[41] Johnston, p. 244.

variables. If a variable possessing autoregressive elements is incorrectly omitted from the structural relationship under study, autoregressive characteristics can be captures by the disturbance term. Similarly, inclusion of an incorrectly specified explanatory variable can lead to transfer of autoregressive elements to the disturbance term if the variable in question was autoregressive in nature.

All desirable small sample properties of the least squares estimators are not attained when the disturbances are autoregressive. Given autoregressive disturbances, the least squares estimators are still unbiased. It can be shown that the least squares estimators of the regression coefficients are not identicial with the best linear unbiased estimator (BLUE) of the regression coefficients. The formulas for the BLUE of the b_i involve ρ, a parameter describing the relationship between successive disturbance terms. In classical least squares estimation it is assumed that the value of this parameter is zero. That the least squares estimators are not efficient is implied in this case also; Kmenta notes that the loss of efficiency can be explained by the fact that the dependence among the disturbances reduces the effective number of independent pieces of information in the sample.[42]

[42] Kmenta, p. 275.

Given autoregressive disturbances, the least squares estimators of the regression coefficients are unbiased but they are not efficient. In order to test hypotheses concerning the estimates parameters or construct confidence intervals around them, these estimated variances of these estimators are also required to be unbiased. However, the variances of $\hat{b}_i$ are not unbiased, and confidence intervals or calculated acceptance regions will be either narrower or wider than the true ones dpending on the direction of the bias. For example, when $\rho > 0$ and ε_i is positively correlated over time, the bias is negative as is fairly common with economic time series. Given this, the caluclated acceptance regions or confidence intervals will often be narrower than they should be for the specified level of signifance or confidence. Given $\rho < 0$, the opposite situations would obtain.

Alternative estimators for the regression coefficients exist when the nonautoregression assumption is not satisfied. These estimation procedures include the first-difference method,[43] the Cochrane-Orcutt iterative method,[44] Aitkens generalized least

[43] Kmenta, p. 289.

[44] Henri Theil, Principles of Econometrics, (New York: John Wileg and Sons, Inc., 1971), p. 256.

squares,[45] and maximum likelihood techniques.[46] These procedures were not employed for this thesis, and will not be discussed here.

Measurement Errors

Given the nature of economic statistics, the assumption that values of the variables in the regression model are measured without error should not be left unchallenged. Errors in sampling, round-off errors, estimated data, and statistics representing concepts different from those postulated in the theoretical relationships could all lead to errors in measurement.

In discussing this problem, the assumption is usually made that the errors in measurement are randomly distributed and have specific probability characteristics. If this assumption is known not to hold, it is likely that sufficient information is available to ameliorate the situation. Employing a two variable regression equation,

$$Y_i = \alpha + BX_i + \varepsilon_i \qquad (4.8)$$

assuming errors in the observations on X,

$$X_i^* = X_i + w_i \qquad (4.9)$$

where,

X_i^* is the observed value of the independent variable,

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[45] Ibid., p. 253.

[46] Kmenta, p. 282.

X_i is the true value of the independent variable, and

w_i is the measurement error.

It is assumed that the error term w_i is serially independent with constant variance and also independent of the true value of X_i. The relevant relationship would be,

$$Y_i = B(X_i^* - w_i) + \varepsilon_i \quad (4.10)$$

or $$Y_i = BX_i^* + (\varepsilon_i - Bw_i) \quad (4.11)$$

In estimating the regression coefficients from the observed data on Y_i and X_i^*, the explanatory variable X_i^* would be contemporaneously correlated with the disturbance term in (4.11) and the least squares estimators of B would be biased and inconsistent.

Given measurement error problems in the independent variables, one of three alternative approaches can be employed. The classical approach can be used with fairly strong assumptions about the probability distribution of the error term. This allows estimation by maximum likelihood techniques. The other two approaches include using methods which group observations (requiring less stringent assumptions about the error terms) and using instrumental variables. Frequently in econometric work, the problem is set aside by assuming that the errors of measurement are relatively so small that they can be safely neglected.

Related Research

Studies in the past have investigated the effects of various wheat and feed grain policy variables on acres of crops planted, employing data aggregated either over the entire U.S. or over multi-state regions of the U.S. Studies involving individual state investigations of the effects of wheat and feed grain policy variables have not been undertaken.

A major contribution to the acreage relationships quantified in this paper was obtained from Houck and Subotnik in their study on soybean supply.[47] An especially useful tool developed in that study was a theoretical model of the "effective support price." They proceeded to develop a distributed lag estimation model which incorporated actual market prices and "effective support prices" in a soybean acreage supply function. In arriving at an estimated regional model, several model specifications were tested per region, and in each case the "effective support prices" yielded markedly better results than did model specifications without the adjustment of support rates. "Effective support prices for other crops

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[47] James P. Houck and Abraham Subotnik, "The U.S. Supply of Soybeans: Regional Acreage Functions," Agricultural Economics Research 21 (October 1969): 99-108.

competing for productive resources were also included in their final equations.

A primary objective in a study by Houck and Ryan, Supply Analysis for Corn in the U.S.,[48] was to develop and test a general theoretical model for evaluating farm commodity program effectiveness. The concept of effective price support was employed in their study, and the existing body of knowledge was augmented by their development of the concept of "weighted diversion payment rates" (DP).

The validity of using DP as a supply inducing price for land diversion was established by estimating corn acres diverted as a function of DP. The significance of this relationship was extremely high and 90 percent of the variation of corn acreage diverted was accounted for by changes in DP. Employing aggregate U.S. data, it was found that a 10 percent increase in DP was associated with an increased diversion of 8.2 million acres.

It was also found in the Houck-Ryan study that the variations in the weighted or effective support price variable (PF) were found to explain variations of corn acreages better than the lagged market price. High intercorrelation between the weighted support price variable and the lagged market price reduced the significance of

[48]Mary E. Ryan and James P. Houck, "Supply Analysis for Corn" pp. 184-191.

both, consequently only the weighted support price variable was retained in their supply equation.

Effects of recent wheat program policy variables on aggregate U.S. planted wheat acreages have been investigated by Garst and Miller.[49] Identification of the major policy variables was a primary objective of their study and in the 1961-1974 time period, five policy variables were found significant. With the inclusion of a lagged market price of wheat, greater than 98 percent of the variation of national planted wheat acreages was accounted for. In this study wheat allotment, additional diversion, and wheat set-aside variables were all expressed as acreage variables, giving rise to the criticism that the variable representing additional diversion was not linearly independent of other explanatory variables. In their final equation, Garst and Miller stated planted wheat acreage as a function of wheat program policy variables and the lagged market price of wheat. However, relevant market prices or government program policy variables of crops competing with wheat for productive resources were not included in the set of explanatory variables.

The effects of government program policy variables as examined by Miller and Hargrove were utilized in a somewhat different

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[49] Gail D. Garst and Thomas A. Miller, "Impact of the Set-Aside Program on the U.S. Wheat Acreages," Agricultural Economics Research 27 (April 1975): 30-37.

manner.[50] An objective of their study was to analyze the response of acreage diversion measures to changing specific provisions of the feed grain program. Data was aggregated and relationships were analyzed on a state-by-state basis. The time period studied was 1961-1969. The dependent variable used in their analyses was "total acres of cropland diverted under the program including both required diversion and optional diversion." A feature of the specification of diversion payment information in this study is the method of stating the payment rate for each possible level of diversion as a different explanatory variable. Given a payment rate for 20 percent diversion, 40 percent diversion, and diversion in excess of 40 percent of eligible cropland, Miller and Hargrove expressed these different payment rates as three separate explanatory variables. Two other variables representing "the maximum percentage of the base eligible for diversion under the program in a given year" and "the absolute maximum diversion allowed, expressed in acres" were also specified. Although the Miller-Hargrove study was measuring an entirely different dependent variable than is being considered in this thesis, familiarity with different government programs leads one to suspect that the number of different discrete diversion levels

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[50] U.S., Department of Agriculture, Factors Affecting Acreage Diverted Under the U.S. Feed Grain Program, by Thomas A. Miller and Stanley H. Hargrove, Economic Research Service 453 (Washington D.C.: Government Printing Office, 1970), 1-37.

in the time period 1961-1974 would give rise to an abundance of explanatory variables. The cost of this method, however, is in terms of lost degrees of freedom since the number of observations is usually quite limited. The Miller-Hargrove model does include the relevant market prices of indigenous crops, thereby including opportunity cost information in the model.

A common objective of the above-mentioned farm commodity program research was the development of an efficient method of specifying explanatory variables in the regression framework. Ordinary least squares regression analysis was employed in each of the above studies. The usual situation in examining farm commodity programs offers few observations and many potential variables to be specified from the existing data base. Familiarity with past farm commodity legislation leads to the conclusion that proper specifications of variables to be analyzed is a primary problem in an inquiry of this nature.

J. B. Penn[51] and Robert G. Hoffman[52] have also made substantial contributions to this area of research, and empirical results

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[51]J. B. Penn, "Econometric Policy Models of Commodity Supply Response" (Ph.D. dissertation, Purdue University, 1973) p. 26-46.

[52]U.S., Department of Agriculture, Wheat-Regional Supply Analysis, by Robert G. Hoffman, Economic Research Service 534 (Washington, D.C.: Government Printing Office, 1973), 15-24.

from their regional studies will be compared to results from this study at a later point.

Chapter 5

EMPIRICAL RESULTS

Firm supply functions were discussed earlier to provide a basis for understanding aggregate supply functions. The response of the state of Montana's wheat and feed grain industry to supply shifters is the primary concern of this thesis. The theory of the firm's production and supply functions and the behavioral nature of the firms comprising the industries relevant to this study is predicated on the assumption of profit maximizing behavior.

Nerlove notes that "the most striking characteristic of the output of a crop is that the farmer has so little control over it. It is the large discrepancy between planned and realized output in any production period that led previous writers to approximate planned output, to which the supply function actually refers, by acreage (planted or harvested)." Variations in measuring the response to farm commodity programs is reduced if the units of measure are stated in terms of acreage planted instead of total bushels produced. Weather, pests, and seasonal peculiarities, which account for much of the discrepancy between planned and realized output, enter supply response analyses only to the extent that acreage planted is effected.[53]

Most past farm commodity programs have focused attention on

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[53] Marc Nerlove, The Dynamics of Supply, (Baltimore: The Johns Hopkins Press, 1958), p. 66.

input control, specifically acreage planted control, while being ultimately concerned with product supply control. Programs are implemented in terms of acreage and compliance is evaluated in acreage terms. Most of the relevant issues of farm commodity legislation are stated in terms of acreage. Hence, acreage supply is deemed more relevant than is product supply in questions concerning the effects of government farm commodity programs.

"If acreage actually represents a good approximation to planned output, then the conditions of production which farmers face can be adequately summarized by a series of 'normal' or expected yields."[54] Evidence that farmers change their notion of "normal" yields is thought to have been detected in the substantial decline in corn acreage in the Southern Great Plains States in the 1930's. "Acreage of a particular crop might then be expressed as a function of, say, the expected acre-values of several alternative crops, where normal acre-value is expected yield times expected 'normal' price."[55] Assuming constant expected yield, the above functional relationship is equivalent to expressing acreage as a function of various prices. The assumption of contant expected yeild is maintained in this study.

In some cases adjustment of the price series by deflation would be

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[54] Ibid, p. 85.

[55] Ibid.

entered in an analysis such as this to remove the effects of the deflator as a supply shifter. Based on past empirical results, initial analyses of this study, and relative constancy of potential adjustment factors such as fertilizer price series and other prices-paid series, variables representing market prices and program prices are not deflated. Implicit in this approach is the assumption that farmers are looking at raw price data rather than price ratios.

Knowledge of the agricultural grains sector, past research, and the neoclassical theory of the firm provided the basis for specification of the Montana wheat and barley equations. The variables specified are those assumed relevant to the individual farm firm. The policy variables included in the set of explanatory variables do not appear in traditional supply relations, but are included since they are parameters faced by the firm in its decision framework. It is felt that aggregation from the firm to the state level may provide justification for inclusion or exclusion of certain variables. Indeed, many possible parameters faced by the individual firms have not been included in the model specification in this thesis. Financial limitations of individual farms are examples of parameters faced by the individual farm firm that are not included in the aggregate model.

Using wheat and barley policy variables and other independent variables, the final maintained hypotheses and estimated coefficients of wheat and barley acreage supply functions for Montana are specified in table 5.1.[56]

Wheat

Equation (5.1) was specified consistent with economic theory and a priori reasoning based upon knowledge of the farm commodity program policies. All signs of the estimated coefficients conformed with prior expectations. The statistical results and the graphic representation (figure 5.1) indicate that the selected variables and the manner in which policy variables were constructed provide good estimates of Montana wheat acreage supply for the time period studied. The estimated coefficients are reasonably large relative to their calculated standard errors and the overall fit of the equation, indicated by R^2, is good. The standard error of the estimate was relatively small, influencing the selection of (5.1) over alternative specifications.

Wheat and barley production compete for a major proportion of tillable cropland in Montana. Neither land characteristics nor the make-up of farmers heavy equipment lines appear to limit the substitutability between these two production processes. The coefficient of AB_t in equation (5.1) which is a measure of the cross effects, indicates that a one acre increase in barley planting is associated with a 0.6 acre decrease in wheat planting, all other variables

[56] Estimated alternative specifications of equations (5.1) and (5.2 can be found in the Appendix.

Table 5.1 Estimates of Equations for Montana Wheat and Barley Acreage Supply.

Equation Number	Dependent Variable	Independent Variables														
		Constant	AW_t	AB_t	AD^w_t	WD^w_t	WD^b_t	WS^w_t	P^w_{t-1}	P^b_{t-1}	D_3	MCB_t	AS^w_t	$\hat{\sigma}$ [b]	$\bar{R}^2$ [c]	D.W. [d]
5.1	AW_t	2903 (9.09)		-0.6098 (4.14)		-470.8 (1.27)[a]	-308.3 (2.25)[a]	1543.9 (9.02)	440.3 (3.78)		-428.9 (4.86)			79.57	.95	2.07
5.2	AB_t	6592 (9.58)	-0.7054 (9.36)		-0.4561 (4.98)		-220.8 (3.83)			1527.7 (7.68)	-323.5 (6.16)	-0.3603 (5.69	-0.4233 (6.34	39.21	.98	2.99

Sources: Data on all variables of table 5.1 was collected from <u>Montana Annual Report</u> Series; U.S.D.A., A.S.C.S., <u>Feed Grain and Wheat Programs Statistical Summary</u>: U.S.D.A., A.S.C.S., and <u>Montana Agricultural Statistics</u>.

Note: Standard error of the coefficient in parentheses.

[a] Coefficient not significant at the 95 percent probability level.

[b] Standard error of the estimate.

[c] Adjusted coefficient of multiple determination.

[d] Durbin-Watson Statistic.

Table 5.2 Variable definitions for Montana wheat and barley acreage supply.

AW_t	= Montana acreage of wheat planted in time period t, in thousands
AB_t	= Montana acreage of barley planted in time period t, in thousands
AD^b_t	= Barley acreage diverted from the production of barley in time period t, in thousands
AD^w_t	= Wheat acreage diverted from the production of wheat in time period t, in thousands
WD^w_t	= Weighted diversion payment rate ($/bu.) for wheat diversion in time period t, weighted by eligible diversion acreage
WD^b_t	= Weighted diversion payment rate ($/bu.) for barley diversion in time period t, weighted by eligible diversion acreage
WS^w_t	= Weighted price support rate ($/bu.) for wheat in time period t, weighted by the proportion of production for which time supports are applicable
WB^b_t	= Weighted price support rate ($/bu.) for barley in time period t, weighted by the proportion of production for which price supports are applicable
P^w_{t-1}	= Market price of all wheat ($/bu.) in Montana, lagged one period
P^b_{t-1}	= Market price of all barley ($/bu.) in Montana, lagged one period
AS^w_t	= Net acreage of land substituted from barley, corn, oats, and rye production into the production of wheat in time period t
D_3	= Dummy variable to account for a change beginning in 1966 when support payments were shifted from inclusion in WS^b_t to inclusion in WD^b_t.[57]
MCB_t	= Montana conserving base acreage

[57]Price support payments were offered to farmers who took part in the 1965 and 1966 feed grain programs. These payments were made for the normal production of a farm's feed grain acreage in 1965; however, they were limited to the acreage planted up to 50 percent of the feed grain base. The per-acre price support payment rate was increased by 50 percent in 1966. These changes permitted wider range of use for that part of the permitted acreage on which no price support payments were made.

Table 5.3 The Direct Elasticity* Estimates of Wheat and Barley Acreage Supply with Respect to the Independent Variables of equations (5.1) and (5.2).

Dependent Variables	Independent Variables										
	AW_t	AB_t	AD_t^w	WD_t^w	WD_t^b	WS_t^w	P_{t-1}^w	P_{t-1}^b	D_3	MCB_t	AS_t^w
AW_t		-.240		-.012	-.008	.487	.154		-.062		
AB_t	-1.791		-.189		-.014			.754	-.119	-1.528	-.048

*Percentage change in the dependent variable given a one percent change in the independent variable. Variables are measured at their respective mean values.

constant. From a percentage standpoint, a one percent change in barley planting would be associated with less than one quarter of one percent change in wheat planting, all other variables constant. The coefficient of AB_t is statistically significant at the 99 percent level.

Diversion of wheat acreage was hypothesized to be an economic activity competitive with wheat production. Specification of a weighted wheat diversion payment, WD_t^w, was intended to capture this effect. However, the estimated coefficient was not significantly different from zero at the 95 percent probability level. The sign of WD_t^w conforms to prior expectations and alternative estimations of wheat acreage supply functions indicate that WD_t^w can be expected to influence the mean value of wheat acreage planted (AW_t). Reestimation of this equation after the deletion of WD_t^w yields unsatisfactory results, since alternative linear combinations of variables were by far inferior. Inclusion of WD_t^w does not appreciably alter the magnitudes of the estimated coefficients of the other independent variables, and was retained based on theoretical grounds.

The coefficient of the variable representing the weighted diversion payment rate for barley, WD_t^b, is statisically significant at the 90 percent probability level. Diversion of barley acreas was originally hypothesized to be an economic activity competing for land resources with wheat production. The sign of WD_t^b conforms to theoretical expectations. The estimated coefficient indicates that an increase in the barley diversion payment rate by one cent per bushel, all other factors held constant, results in decreased wheat acreage planted by approximately three thousand acres in the state of Montana. The estimated elasticity of wheat acreage supply with respect to the weighted diversion payment rate for barley diversion is -0.008. This indicates that a one percent increase in the weighted diversion payment rate for barley diversion would be associated with a nearly imperceptible decrease in wheat planting. The estimated elasticity of wheat acreage supply with respect to the weighted diversion payment rate for wheat acreage diversion is 50 percent larger than the above mentioned elasticity estimate, however, it also is very small. Diversion payment rates for both wheat and barley acreage diversion appear to influence the level of wheat planting very little.

Two variables representative of own price of wheat, WS^w_t and P^w_{t-1}, play highly significant and relatively large roles in explaining wheat acreage adjustments. Consistent with prior expectation, the weighted price support rate for wheat was estimated as having a much larger marginal impact on acres of wheat planted than own market price lagged one period. The estimated coefficient of WS^w_t indicates that a one cent increase in the weighted price support rate for wheat is associated with an increase of approximately 15,500 acres of wheat planted, holding constant all other factors. The estimated coefficient of WS^w_t is significant at the 0.01 level. The elasticity of acreage supply with respect to weighted support price, computed at the mean values of the variables, is 0.487. This implies that a 10 percent increase in weighted support price increases wheat acres by nearly 5 percent. It was expected that the estimate of elasticity of wheat acreage supply with respect to weighted support price would be greater than estimates of elasticity of supply of wheat with respect to the free market price. Tweeten estimated short-run price elasticity of supply for wheat at 0.3.[58] Cochrane reports the price elasticity of supply for wheat within the range of 0.1 to 0.2.[59]

As originally hypothesized, lagged market price of wheat, in addition to the weighted support price of wheat is positively related to the acreage planted to wheat. The estimated coefficient of P^{W}_{t-1} indicates that a one cent positive difference of lagged market price of wheat would lead to a 4,400 acre increase of wheat planted in the state of Montana, all other variables held constant. The estimated elasticity of wheat acreage supply with respect to market price of wheat lagged one period, computed at the data means, is 0.155. Thus a 10 percent increase in the lagged market price of wheat increases wheat acreage planted in Montana by 1.5 percent.

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[58] Tweeten, p. 243

[59] Willard W. Cochrane, "Conceptualizing the Supply Relation in Agriculture", Journal of Farm Economics 37 (1955): p. 1164.

Dummy variable D_3 plays a significant role in determining the mean value of AW_t. Apparently the method of incorporating price support payments into either WS_t^b or WD_t^b for the time period 1961 through 1973 greatly affected the value of the dependent variable AW_t. For the period 1966 through 1973, price support payments were included in the calculation of WD_t^b. It was originally decided to include D_3 as an explanatory variable whenever WS_t^b or WD_t^b was used on the right-hand-side of (5.1).

The historical predictive ability of equation (5.1) is given in figure 5.1 where a comparison of actual and estimated values of wheat acres planted are given. For the sample period 1961-1973, not only was the average percentage prediction error small (1.192 percent), but all turning points were correctly estimated.

In making statements about past events, the quality of estimates of past events should be considered. Previous researchers have employed Theil's inequality coefficient (U) for evaluating the quality of a set of forecasts.[60] J. B. Penn converted Theil's inequality coefficient for use in evaluating forecasts in actual values of variables as follows:

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[60] Henri Theil, Applied Econometric Forecasting, (Chicago: Rand McNally and Company, 1966).

[61] J. B. Penn, "Econometric Policy Models of Commodity Supply Response" (Ph.D. dissertation, Purdue University, 1973), p. 65.

$$\mu = \sqrt{\frac{\Sigma(A_j^* - P_j)^2}{\Sigma(A_j - A_{j-1})^2}}$$

where, A_j = Actual value of relevant variable in time period t,

A_{j-1} = Actual value of relevant variable in time period t-1,

A_j^* = Actual change in value of the relevant variable from one period to the next,

P_j = Predicted value of the relevant variable in time period t.

U may take values from zero to infinity. When U equals zero for a given set of forecasts, this indicates that the model forecasts perfectly, and when U equals unity, the prediction procedure yields the same root mean square (RMS) prediction error as naive no-change extrapolation. The possibility of an infinitely large inequality coefficient implies that it is possible to do considerably worse than by extrapolating on a no-change basis. An inequality coefficient of 0.65 calculated from an actual and estimated data series indicates that the RMS prediction error is equal to 65 percent of the RMS error that would have been observed if the forecaster had confined himself to no-change extrapolation.[62] The Theil inequality coefficient corresponding to equation (5.1) is 0.0984.

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[62]Thiel, p. 28.

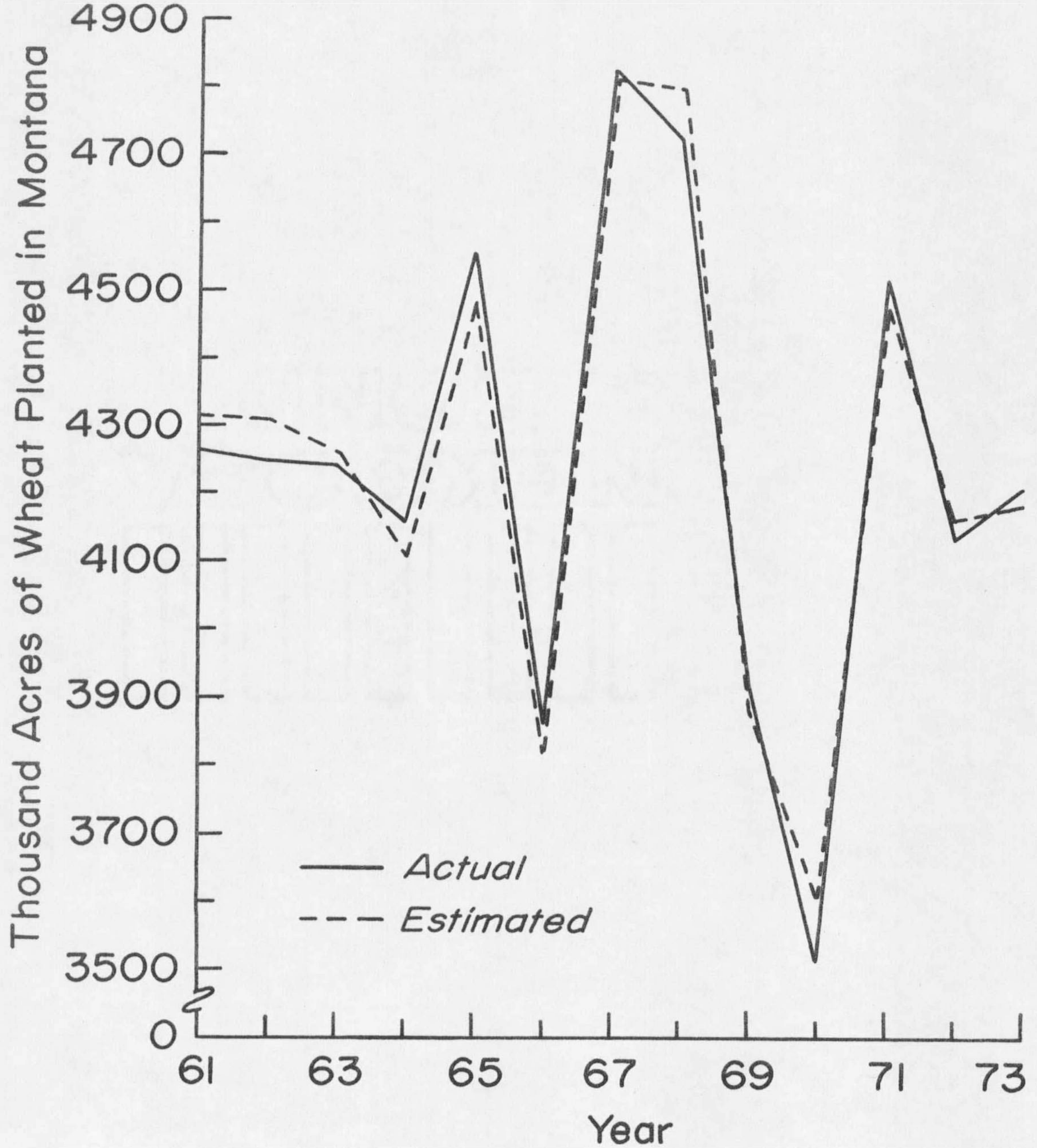

Figure 5.1 Actual and estimated acres of wheat planted in Montana.

Barley

The specification of equation (5.2) was based on economic theory and an understanding of the farm commodity program policies. All signs of the estimated coefficients conformed with a priori expectations. The graph of actual and estimated acreages of barley planted for the period 1961-1973, figure 5.2, and the statistical results indicate that the selected linear combination of variables of equation (5.2) provide good estimates of Montana barley acreage supply for the time period studied. The estimated coefficients are large enough relative to their calculated standard errors to provide reasonable levels of confidence in their estimation. As a measure of fit, R^2 is good and the standard error of the estimate is small relative to the magnitude of the dependent variable, AB_t.

The magnitude of the estimated coefficient specific to wheat acreage (AW_t) in equation (5.2) supports the original hypothesis of a strongly competitive relationship between wheat and barley production in the state of Montana. The estimated coefficient indicates that for each additional acre of wheat planted in the state of Montana, 0.7 acre of barley is foregone, holding all other variables constant. Note that the cross effects between wheat and barley are not symmetric. It can be seen from equations (5.1) and (5.2) that the marginal impact of wheat acreage planted on barley acres planted is greater than the marginal impact of barley acreage planted on wheat acres planted. In percentage terms, the elasticity of supply of barley acres with respect to wheat acres is -1.791.

Wheat acreage diverted from production, AD_t^w, was hypothesized to be an economic activity competing for tillable land with barley production. The sign and magnitude of the estimated coefficient of AD_t^w support this hypothesis and indicate a significant relationship. The estimated coefficient is statistically significant at the 99 percent probability level. Holding all other variables constant in equation (5.2), the estimated coefficient of AD_t^w indicates that an additional acre of land diverted from wheat production is associated with a 0.46 acre reduction of barley planting. Alternatively stated, a one percent increase of diversion from wheat production would be associated with a -0.189 percent decrease of barley planting.

The diversion payment rate for diverting acreage from the production of barley, represented by WD_t^b, was hypothesized to be a measure of opportunity cost of producing barley in equation (5.2). The negative estimated coefficient of WD_t^b in (5.2) supports this hypothesis. This estimation indicates that for an additional one cent per bushel increment received by farmers for diverting acreage from the production of barley, barley acreage would be reduced by approximately 2,200 acres. The one cent per bushel increment mentioned above would be applicable to normal production. The elasticity of barley acreage supply with respect to the weighted barley diversion payment, calculated at the data means, is -0.014.

A variable representing the weighted support price of barley was not successfully included as an explanatory variable in the barley acreage supply function. When included in a set of regressors of the barley acreage supply function, the calculated standard error of the coefficient was very large relative to the size of the estimated coefficient and the standard error of the equation increased substantially.

The market price of barley lagged one period, P^b_{t-1}, was the only variable representative of a grain market price that entered equation (5.2) at any reasonable level of signficance. Conforming with prior expectations, P^b_{t-1} was a very important variable in determing the mean value of barley acreage planted, displaying a strong positive relationship. The estimated coefficient of P^b_{t-1} indicates that a one cent positive difference of P^b_{t-1} would be associated with a positive change of approximately 15,277 acres of barley planted, holding constant all other variables. The estimated coefficient is significant at the 99 percent probability level. The estimated elasticity of barley acreage supply with respect to the lagged market price of barley is 0.75. Hence a 10 percent increase in lagged market price leads to a 7.5 percent increase in barley acreage planted.

Conserving base acreage is defined as the average acreage that a farm devoted to summer fallow, conserving crops, and idle acres in the period 1959-1960. Maintenance of conserving base acreage was a basic requirement for taking part in wheat or feed grain programs for the period of 1961-1973. Total conserving base acreage for Montana remained at a constant level from 1961 to 1965 and decreased steadily from 1966 to 1973. Maintenance of conserving base acreage was hypothesized to be a constraint on both wheat and barley production. The estimated coefficient of MCB_t indicates that for each acre of land released from the conserving base in Montana, holding all other variables constant, barley acres planted would increase by 0.36 acre.

Dummy variable D_3 displays a negative relationship with barley acreage planted. Recall that a negative relationship also existed between D_3 and wheat acreage planted. The consistency of this situation can be seen since D_3 signifies a gain in value of the weighted diversion payment rate variable and a reduction in value of the weighted price support variable. That a structural change in the commodity program policies occurred between 1965 and 1966 is supported by the magnitude and statistical significance of D_3.

The net acreage of land substituted from the production of other crops into the production of wheat, AS_t^w, influences barley acreage planted substantially. The major proportion of this substitution was from acreage designated for barley production to wheat production, and the hypothesized negative relationship between AS_t^w and AB_t was statistically verified. Holding all other variables constant in (5.2), for each additional acre substituted from the production of other crops to the production of wheat, barley acreage was decreased by 0.42 acre.

Estimated barley acreage planted and actual barley acreage planted for the time period 1961-1973 are given in figure 5.2. In this estimation, all turning points were correctly estimated and the average percentage prediction error was 1.28 percent.

The Theil inequality coefficient corresponding to equation (5.2) and figure 5.2 is 0.0870. This means that the root mean square error calculated from actual and estimated data points on figure 5.2 is equal to approximately nine percent of the root mean square error that would have been expected from a naive no-change extrapolation of the actual annual data for that period.

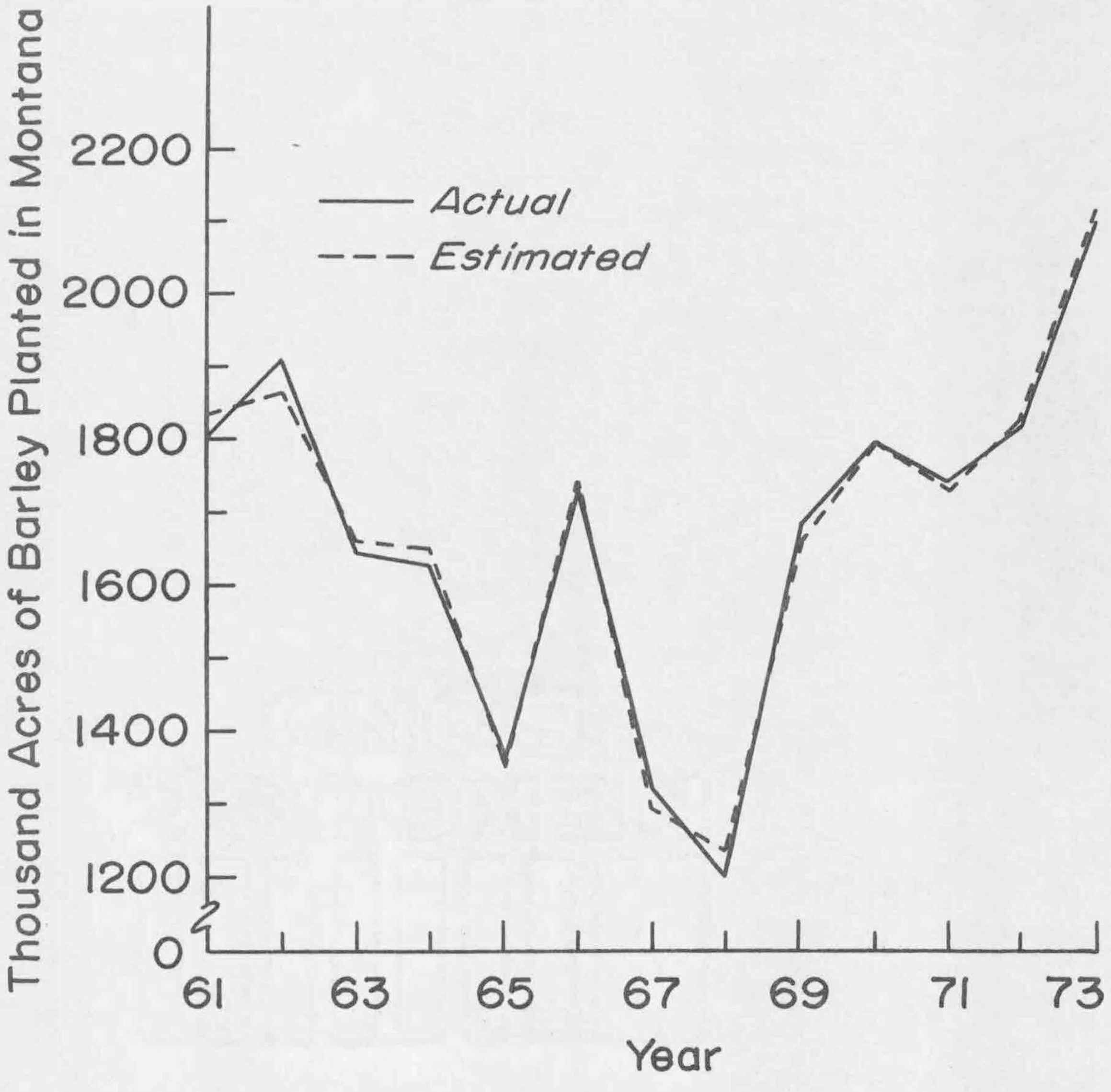

Figure 5.2. Actual and estimated acres of barley planted in Montana.

Chapter 6

SUMMARY AND CONCLUSIONS

The objectives of this study were: to identify and statistically estimate the parameters specific to government farm commodity programs which determined the number of acres Montana farmers committed to wheat and barley production during the period 1961-1973, to estimate the elasticities of wheat and barley acreage supply with respect to market prices and government program policy variables, and to estimate the marginal rates of substitution in production between wheat and barley in Montana over the time period studied.

A brief review of past farm commodity legislation was undertaken to gain an understanding of the goals of this legislation and the tools employed to achieve these goals. The American farm problem is comprised of a very inelastic demand for farm products, continued overproduction of these products, and relatively too many farmers sharing the net returns from agricultural production.

The inability to recognize the farm problem led to legislation aimed at correcting certain symptoms. This approach in turn has given rise to other symptoms. Supporting depressed market prices of farm commodities above equilibrium levels has inevitably led to surpluses of these commodities coupled with high storage costs. Efforts to raise farm income have similarly led to surpluses of farm commodities in addition to increasing the capability of farmers to invest in productive inputs, compounding the problem in the immediate future. The implementation of soil conservation programs to conserve soil resources or the use of soil conservation programs as vehicles for transferring income to farmers has led to increased productivity of American farms, thereby augmenting the capacity of American farmers to overproduce.

Two kinds of agricultural commodity production controls authorized under the Agricultural Adjustment Act of 1938, coupled with a price support system, have been used in attacking the American farm problem. Compulsory marketing quotas, expressed in terms of normal yields per acre, were in effect from 1954 through 1963 in the U.S. wheat sector. Marketing quotas were compulsory in that producers who did not comply were obliged to pay a penalty on each bushel of wheat produced on non-allotment acres. Marketing quotas had to be approved in a producer referendum for each year in which they were proclaimed. The other type of production control authorized under the Agricultural Adjustment Act of 1938 was voluntary acreage controls. Compliance with voluntary controls has typically provided eligibility for price support loans and other benefits such as diversion payments and set-aside payments. From 1964 through 1973 controls on wheat production were voluntary.

Production controls on feed grains from 1961 through 1973 were also voluntary.

Price supports have been an integral part of farm commodity legislation since 1933. The primary objective of support prices has been to increase real farm income. Although supply theory relates that relatively higher prices of a commodity will increase its supply, a supply-adjusting role for support prices has not been exploited. In fact, during periods of depressed market prices and surpluses of farm commodities, policymakers would like to ignore the effects of increased support prices on supply.

Using traditional economic production and supply theory, an econometric model was specified and employed in Montana wheat and barley acreage supply analyses. The general economic model stated acreage planted of a given Montana crop as a function of: (1) relevant open-market forces assumed to affect planting decisions in the State of Montana; (2) relevant government farm program policies; and, (3) variables incorporating unspecified economic and noneconomic factors and random effects. The net effect of the unspecified economic and noneconomic factors and random effects is assumed to be a mean-zero random variable with constant and finite variance over the sample period. The assumed existence of this random variable permits the use of ordinary least squares to estimate the marginal effects of the identifiable predetermined variables in the econometric model.

The reliability of acreage estimations (5.1) and (5.2) is enhanced by the small geographical area considered in this study and by the introduction of prices and acreages of competitive crops when estimating the acres planted of a given Montana crop. Long-run shifts in acreage of various crops from one geographical area to another can change the importance of different products in relation to a particular crop. Given limited ability to include prices of other crops in the specified set of regressors, these long-run shifts in acreage can change the behavioral relationships between the dependent and the independent variables. By the same token, these shifts could change the weights of various prices in an index of "other" prices, employed as an explanatory variable.

A significant finding of this study is the degree of responsiveness of Montana wheat and barley producers to different policy variables. The calculated elasticities of wheat and barley acreage supply with respect to the weighted diversion payment rates indicate that a very large increase in weighted diversion payment rates for wheat and barley acreage diversion would be associated with small negative change of either wheat or barley acreage planted. This result is consistent with past studies. Point estimates of elasticity of wheat acreage supply with respect to wheat diversion payment measures were not found. Hoffman estimated the elasticity of wheat acreage supply with respect to the effective support rate for wheat at 0.39 in the Northern Plains, and indicated that the impact of the effective voluntary diversion payment rate was much less than the impact of the effective support rate. Elasticity of barley acreage supply with respect to a weighted barley diversion payment rate, calculated from Abel-Ryan study, is 0.155.[63]

One possible explanation of the unresponsiveness of Montana agricultural production to diversion payment measures is that land is a relatively abundant resource in Montana and is used extensively. Given a relatively higher diversion payment rate for either wheat or barley acreage diversion, other inputs could be employed more intensively to achieve certain production levels. Resource allocation practiced by Montana farmers, substituting land resources for other productive inputs such as fertilizer, labor, and irrigation equipment, could contribute to the interpretation of this result.

Montana agriculture is characterized by relatively few production alternatives of tillable land. Given an abundant supply

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[63]See U.S., Department of Agriculture, Wheat-Regional Supply Analysis, by Robert G. Hoffman, Economic Research Service 534 (Washington, D.C.: Government Printing Office, 1973), pp. 15-24; and Mary E. Ryan and Martin E. Abel, "Oats and Barley Acreage Response to Government Programs," Agricultural Economics Research 25 (October 1973): pp. 105-114.

of agricultural land, this would imply a relatively low opportunity cost of wheat and barley production. Relatively low opportunity costs of any productive input might lead to greater utilization rates.

Another possible explanation of the general unresponsiveness of wheat and barley acreages to weighted wheat and barley diversion payment rates is that the respective diversion payment rates are so small compared to returns from crop production that only few marginal acres are attracted to acreage diversion.

Possible goals of the relevant farm commodity legislation should also be considered here. The extent to which diversion or set-aside payments are actually intended to reduce crop acres is not known; however, the extent to which diversion or set-aside payments are actually intended to increase farm income cannot be ignored.

The weighted support price of wheat was greater than the lagged market price of wheat for only six of the thirteen observations used in this study. Nevertheless, the elasticity of wheat acreage supply with respect to the weighted support price was more than three times greater than the elasticity of wheat acreage supply with respect to lagged market price of wheat. The results of this study strongly suggest that the price which farmers take into account when planning their acreage is reflective of some announced support rate; the price per bushel and the proportion of farmers' production eligible for the announced support rate are both taken into account in the farmers' decision making process. The higher the degree of certainty that farmers can place on government price supports as compared to some market price would lead one to expect the profit maximizing farmer to heed government price supports more than open-market prices.

Equation (5.2) indicated that Montana farmers paid little notice to price support rates for barley for the time period 1961-1973. This was anticipated since the free market price of barley (lagged one period) was greater than the weighted support price of barley for ten of the thirteen observations of this study. Consequently, the lagged market price of barley was the most important market price influencing farmers' barley planting decisions over the time span of this study.

Avoiding production control features of government programs while managing to gather benefits of these programs would most often be determined as profit maximizing behavior. Slippage, the tendency of a given acreage or budget outlay to remove less output over time, would include this practice. Slippage would provide an explanation of the coefficient specific to net acreage of land substituted from the production of other crops into the production of wheat, AS_t^w, in equation (5.2). First it should be noted that nearly all the crop acres given up were barley acres. One would expect acreage substituted from the production of barley to the production of wheat to be nearly directly related to decreased production of barley. The coefficient of AS_t^w indicated that for each acre substituted from the production of barley to the production of wheat, barley acreage planted is decreased by less than one-half acre. One might suspect that more substitution appears to be taking place for commodity program purposes than is actually taking place.

Price elasticities of acreage supply calculated in this study are higher than those found by earlier investigators. Kohls and Paarlberg estimated an elasticity of acreage with respect to a one year lagged wheat price deflated by an index of all prices received by farmers (1910-14=100) of about 0.2 for wheat. Inclusion of a variable representing weighted support price of wheat in estimating wheat acreage planted in Montana is thought to have greatly reduced the elasticity of acreage with respect to lagged price of wheat. That the estimated elasticity of wheat acreage with respect to weighted support price of wheat is considerably greater than the estimate found by Kohls and Paarlberg,[64] is thought to be due to the relevant regional effect of the variable particular to the

[64] R.L. Kohls and Don Paarlberg, "Short-Time Response of Agricultural Production to Price and Other Factors," Purdue University Agricultural Experiment Station Bulletin 555 (1950), cited by Marc Nerlove, The Dynamics of Supply, p. 21.

State of Montana.

Finally, it can be seen from both the estimated regression coefficient of Montana conserving base acreage, MCB_t, and the estimated elasticity of barley acreage with respect to MCB_t, that any given reduction in the Montana conserving base would be associated with a proportionally larger increase in barley plantings relative to the corresponding decrease in conserving base.

Results from acreage studies such as this must be viewed cautiously if inferences are to be made concerning commodity supply. Two main factors must be noted in attempting such an inference. First, land is not a homogeneous factor of production. Both soil characteristics of individual parcels of land and the location of any producer on his production expansion path can seriously affect productivities of land. It is generally concluded that of the acreage eligible for diversion or set-aside payments, the least productive land or the land at the margin would be the first to be removed from production; this would not be expected to be equivalent to the effects on total production of the removal of other land.

Another important factor to be considered is that when the planned output of a crop is expanded, all inputs need not be expanded proportionately. Output per unit of any one factor would change.

This study has shown that Montana farmers are generally more responsive to market prices than has been indicated by previous studies of other regions. The historical orientation of Montana agriculture to export through West Coast markets could explain the relatively greater responsiveness of Montana farmers to market prices. Also shown in this study is that Montana wheat and barley production is nearly unresponsive to past levels of diversion or set-aside payments offered by the federal government. These findings are generally consistent with the present day understanding of the nature of Montana agriculture and could be employed to evaluate the effects of future farm programs on Montana agriculture.

APPENDIX

Table 1 Alternative Estimations of Montana Wheat Acreage Supply

Equation Number	Dependent Variable	Independent Variables							R^{2}[c]	$\hat{\sigma}$[b]	DW[d]
		Constant	AB_t	AD_t[b]	WD_t^w	WS_t^w	P^w_{t-1}	D_3			
5.1a	AW_t	3183 (7.05)	-0.49 (-3.12)	-.314 (-1.57)[a]		1731 (6.63		-604.9 (-5.54)	.8700	128.91	
5.1b	AW_t	2693 (7.01)	-0.48 (-2.82)		-895.36 (-2.24)[a]	1622 (7.70)	367 (2.61)	-431.1 (-3.88)	.9212	100.39	2.35
5.1c	AW_t	2752 (6.58)	-0.476 (-2.64)	-.103 (-.55)[a]	-799.26 (-1.75)[a]	1618 (7.28)	334 (2.09)[a]	-442 (-3.73)	.9125	105.76	2.17

Note: Standard error of the coefficient in parenthesis.

[a]Coefficient not significant at the 95 percent probability level.

[b]Standard error of the estimate.

[c]Adjusted coefficient of multiple determination.

[d]Durbin-Watson Statistic.

Table 2 Alternative Estimations of Montana Barley Acreage Supply

Equation Number	Dependent Variable	Independent Variables											$R^{2\,c}$	$\hat{\sigma}^{b}$	DW^{d}
		Constant	AW_t	AD^w_t	WD^w_t	WD^b_t	WS^b	P^b_{t-1}	P^w_{t-1}	MCB	AS^w	D^3	T		
5.2a	AB_t	6334 (4.47)	-0.6566 (-4.33)	-0.45 (-2.29)			+34 (.13)[a]	1668 (3.57)	.168 (1.00)[a]	-.34 (-2.42)[a]	-.51 (-2.97)	-339 (-2.85)		.9031	77.68	2.85
5.2b	AB_t	6253 (4.41)	-0.6432 (-4.26)	-0.43 (2.20)[a]			-23 (-.09)[a]	1445 (3.52)		-.35 (-2.50)[a]	-.404 (-3.00)	-279 (-2.72)		.9032	77.64	2.56
5.2c	AB_t	12105 (8.32)	-0.5895 (-6.23	-0.163 (1.41)[a]		-101.73 (-1.05)[a]		1212 (4.52)		-.45 (-5.17)			-.83 (-7.28)	.9238	68.89	

Note: Standard error of the coefficient in parenthesis.

[a]Coefficient not significant at the 95 percent probability level.

[b]Standard error of the estimate.

[c]Adjusted coefficient of multiple determination.

[d]Durbin-Watson Statistic.

Table 3 Data Matrix

Wheat acres planted in Montana in time t	Montana Wheat Allotment in time t	Montana Wheat Allotment in time t	Montana Conserving Base Acreage in time t	Net substitution acres in Montana Substitution of wheat for others	Weighted price support rate in Montana for wheat $/bu in time t	Weighted price support rate in Montana for wheat $/bu in time t_1	Weighted price support rate in Montana for wheat $/bu in time t_2	Weighted price support rate in Montana for barley $/bu in time t	Weighted price support rate in Montana for barley $/bu. in time t_1	Weighted price support rate in Montana for barley $/bu in time t_2	Weighted Diversion payment rate in Montana for barley diversion $/bu in time t_1	Price Deflation	Weighted Diversion payment rate in Montana for wheat diversion $/bu in time t	
WA_t	MWA_t	MWA_t	MCB_t	AS^w_t	WSW_t	WSW_{t-1}	WSW_{t-2}	WSB_t	WSB_{t-1}	WSB_{t-2}	WDW_t	Pd	WDB_t	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4262	4013.5	4013.5	7674	0	1.15	1.14 (1960)	1.17 (1959)	.93	.77	.77	0	93	0	0
4248	4033.9	4033.9	7674	0	1.24	1.15	1.14 (1960)	.65	.93	.77	.149	94	.258	.120
4246	4026.2	4026.2	7674	0	1.18	1.24	1.15	.67	.65	.93	.086	95	.176	.176
4156	3640.4	3640.4	7674	0	.94	1.18	1.24	.62	.67	.65	.139	94	.033	.033
4551	3652.3	3652.3	7674	589.1	1.25	.94	1.18	.62	.62	.67	.139	96	.073	.073
3885	3538.5	3538.5	7674	160.4	1.29	1.25	.94	.52	.62	.62	.175	99	.141	.141
4825	4696.7	4696.7	7608	377.2	1.61	1.29	1.25	.90	.52	.62	0	100	0	0
4722	4085.0	4085.0	7546	691.9	1.61	1.61	1.29	.90	.90	.52	0	102	0	0
3920	3555.6	3555.6	7164	344.9	1.33	1.61	1.61	.54	.90	.90	.170	106	.178	.178
3506	3137.7	3137.7	6797	303.6	1.17	1.33	1.61	.54	.54	.90	.162	110	.157	.157
4516	1383.6	3055.0	5786	0	1.61	1.17	1.33	.81	.54	.54	0	115	0	0
4130	1410.5	3114.4	5523	0	1.55	1.61	1.17	.86	.81	.54	.202	122	.156	.156
4235	1347.5	2975.3	5699	0	1.51	1.55	1.61	.86	.86	.81	.128	146	.281	.281

Table 3 Data Matrix Cont.

Average price of all wheat in Montana \$/bu in time t	Average price of all wheat in Montana \$/bu in time t_1	Average price of all wheat in Montana \$/bu in time t_2	ESW	Average price of barley in Montana \$/bu in time t	Average price of barley in Montana \$/bu in time t_1	Average price of barley in Montana \$/bu in time t_2	D_1 S	D_2 B	D_3 SP	T	Barley acres planted in Montana in time t BA_t	Wheat acres diverted AD^w_t	Barley acres diverted AD^b_t
16	17	18	19	20	21	22	23	24	25	26	27	28	29
1.86	1.66	1.66	1.25	.86	.66	.67	0	0	0	61	1801	0000.0	0000.0
2.00	1.86	1.66	1.18	.74	.86	.66	0	1	0	62	1909	0548.2	0118.4
1.82	2.00	1.86	1.28	.72	.74	.86	0	1	0	63	1642	0271.5	0227.1
1.27	1.82	2.00	1.09	.78	.72	.74	0	1	0	64	1626	0681.2	0291.8
1.23	1.27	1.82	1.53	.87	.78	.72	1	1	0	65	1366	0391.5	0278.5
1.49	1.23	1.27	1.63	.87	.87	.78	1	1	1	66	1735	0528.3	0076.3
1.29	1.49	1.23	1.66	.86	.87	.87	1	0	1	67	1319		
1.16	1.29	1.49	1.67	.78	.86	.87	1	0	1	68	1200		
1.23	1.16	1.29	1.67	.71	.78	.86	1	1	1	69	1680	0609.5	0256.6
1.31	1.23	1.16	1.48	.78	.71	.78	1	1	1	70	1800	1028.9	0272.2
1.23	1.31	1.23	1.66	.88	.78	.71	0	0	1	71	1740	1016.7	
1.88	1.23	1.31	1.59	1.22	.88	.78	0	1	1	72	1820	1845.4	0698.3
4.30	1.88	1.23	1.42	1.20	1.22	.88	0	1	1	73	2100	2078.5	0182.6

Table 4. Correlation Matrix

	WA_t x1	MWA^*_t x2	MWA_t x3	MCB_t x4	AS^w_t x5	WS^w_t x6	WS^w_{t-1} x7	WS^w_{t-2} x8	WS^b_t x9	WS^t_{t-1} x10	WS^b_{t-2} x11	WD^w_t x12
x2	.193563											
x3	.542530	.882769										
x4	.131339	.956477	.776500									
x5	.311992	.421132	.316405	.349771								
x6	.520773	-.383782	-.044224	-.534727	.262050							
x7	-.149529	-.324880	-.235618	-.468743	.115330	.501822						
x8	-.278219	-.330865	-.415793	-.441462	.140318	.146904	.482715					
x9	.665176	-.182932	.218758	-.314311	-.057885	.598659	.239529	-.031403				
x10	-.007521	-.048306	-.008032	-.059586	-.028458	.082521	.527891	.147855	.167550			
x11	-.554681	.194190	-.033184	.176316	-.190114	-.516374	-.012778	.449558	-.438994	.111918		
x12	-.244436	.104777	.040133	.142568	-.279580	-.341176	-.043107	-.162318	-.336757	-.061709	.536404	
x13	-.121746	-.840423	-.692479	-.885682	-.216135	.528071	.579218	.579127	.300181	.186205	-.013522	-.137584
x14	-.526606	-.286451	-.375203	-.263119	-.338416	-.118570	.279001	.259467	-.382752	.437739	.575401	.427933
x15	-.585057	-.403025	-.511188	-.379188	-.278267	-.072027	.405176	.375953	-.363610	.306383	.586787	.483142
x16	-.070837	-.481053	-.342388	-.464079	-.446989	.143551	.275114	.286416	.301289	.388448	.275916	.096818
x17	.139333	.146915	.258982	.187694	-.565888	-.369882	-.243141	-.115893	.171215	.176312	.369508	.431967
x18	.202182	.440350	.359636	.580129	-.090860	-.661976	-.531321	-.438537	-.131463	.098270	.098525	.377694
x19	.181985	-.212314	-.126220	-.316132	.558935	.763001	.425213	.174295	.111761	-.160564	-.387197	-.307160
x20	.014597	-.660466	-.491742	-.653546	-.278810	.352584	.373545	.358438	.380357	.248015	.007999	-.111092
x21	.162385	-.467753	-.268518	-.490270	-.071578	.537067	.464138	.248802	.292216	.354329	-.106668	-.124891
x22	.094511	.012593	.091262	-.123656	.342969	.423698	.690625	.404862	.114028	.076827	.148100	.268120
x23	-.030927	.428636	.231661	.382879	.861078	.158283	.112194	.136775	-.339644	-.220226	-.038280	-.240844
x24	-.650063	-.166779	-.419861	-.051922	-.217033	-.491628	.033833	.079647	-.718214	.162427	.469525	.508550
x25	-.106543	-.435087	-.352998	-.564442	.238967	.720057	.694457	.427160	.141337	-.056416	-.267607	-.347018
x26	-.122514	-.767551	-.669558	-.852605	.082380	.652028	.654000	.600491	.161570	-.007116	-.200384	-.235261
x27	-.597246	-.584047	-.612817	-.519023	-.793512	-.189694	.101136	.235780	-.111289	.244303	.409513	.116953
x28	-.373125	-.902751	-.842394	-.881757	-.443219	.226210	.415506	.414240	.032196	.159046	.012351	-.002586
x29	-.405600	-.421384	-.469851	-.418295	-.187934	-.136151	.293082	.076840	-.207649	.143036	.058363	.318637

	P^d x13	WD^b_t x14	x15	P^w_t x16	P^w_{t-1} x17	P^w_{t-2} x18	x19	P^b_t x20	P^b_{t-1} x21	P^b_{t-2} x22	D_1 x23	D_2 x24
x14	.434031											
x15	.578931	.924861										
x16	.735553	.631240	.654741									
x17	-.046906	.288391	.168037	.531445								
x18	-.607663	-.149266	-.246144	-.159922	.548087							
x19	.244437	-.239562	-.053524	-.252866	-.813331	-.724907						
x20	.883513	.448153	.562308	.912720	.246000	-.334151	.027521					
x21	.776257	.518658	.543930	.802154	.178603	-.412591	.205128	.869964				
x22	.387283	.159942	.374709	.214796	-.052591	-.351934	.448932	.305102	.457226			
x23	-.215446	-.194456	-.102790	-.474590	-.682464	-.338210	.637941	-.319282	-.095416	.367628		
x24	.135903	.772125	.775556	.258935	.129776	.151264	-.302512	.171914	.164704	.026921	-.051434	
x25	.607739	.030878	.188695	.060581	-.612680	-.921380	.813133	.309050	.435861	.550694	.414758	-.184466
x26	.864295	.194502	.379008	.292901	-.456849	-.759008	.630213	.572268	.552941	.472166	.123718	.044544
x27	.588656	.683493	.637957	.674402	.333311	-.226060	-.374587	.528526	.331856	-.254401	-.600534	.437069
x28	.876643	.566598	.656574	.632802	-.008174	-.409412	.049826	.756960	.599793	.100192	-.388155	.460492
x29	.283076	.391211	.477665	.086984	-.143618	.064698	-.063994	.181623	.036794	.037798	-.186276	.661072

	D_3 x25	T x26	BA_t x27	AD^w_t x28	AD^b_t x29
x26	.845154				
x27	.011061	.202062			
x28	.391138	.741896	.693636		
x29	.006763	.320851	.250492	.596637	

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