Price and substitution elasticities for wheat related to price policies for wheat
by Charles Yen-Do Liu

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Economics at Montana State College
Montana State University

Abstract:
This thesis was primarily designed to discover the price elasticity of hard spring wheat, and the substitution elasticities between it and hard winter and soft winter wheats. Furthermore, it Was anticipated that these relationships would lend guidance and direction for a more effective price policy for wheat.

Part I lays the groundwork for the thesis by presenting the general problem situation and the methodology to be employed. Also it covers the objectives and the hypothesis.

Part II describes the data and the selection of the variables used in the multiple regression analysis. The results and the shortcomings of this analysis are also included in this section.

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Any error or deficiency in this thesis is the responsibility of the author.

ABSTRACT

This thesis was primarily designed to discover the price elasticity of hard spring wheat, and the substitution elasticities between it and hard winter and soft winter wheats. Furthermore, it was anticipated that these relationships would lend guidance and direction for a more effective price policy for wheat.

Part I lays the groundwork for the thesis by presenting the general problem situation and the methodology to be employed. Also it covers the objectives and the hypothesis.

Part II describes the data and the selection of the variables used in the multiple regression analysis. The results and the shortcomings of this analysis are also included in this section.

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PART I

THE PROBLEM

Introduction and Setting

Bread has been an important item in the human diet since man changed his type of life from hunting and fishing to agriculture. Wheat is still one of the basic foods even though in many countries including the United States per capita consumption has been declining for several years.

The demand for hard red spring wheat depends almost solely on the demand for flour except the small amount used for seed, feed and industrial uses. The demand for flour in turn depends on the income of the consumer, the price of substitutes and the habit patterns of the consumer. If the demand for flour is inelastic, which is the actual situation, so is the demand for hard red spring wheat.[1/] Furthermore, domestic consumption of hard red spring wheat also depends largely on the movement of wheat between markets. This means that it also depends on the prices of other kinds of wheat which change because of either a change in current production, a change in protein content or a change in both.

Annually, varying quantities of hard red spring wheat flow into the Southwest for blending with hard red winter wheat. The price and the protein content of hard red winter wheat influences the amount of hard red

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1/ With the qualification that the marketing margin may be of such a nature as to change the elasticity of the derived demand for wheat from that of the consumer demand for bread.

spring wheat shipped into the Southwestern states. If the miller in the Southwest realizes that there is price advantage in buying hard red spring wheat over the low protein content of hard red winter wheat in the market, he will enter the hard red spring wheat market and purchase spring wheat to strengthen the hard red winter wheat in order to fulfill the necessary requirement of flour orders. On the other hand, if the millers feel that there is no price advantage in doing so, less hard red spring wheat will be purchased for this purpose.[1/] A similar situation occurs with soft red winter wheat but to a lesser extent than in the hard red winter wheat area.

Likewise, millers in the hard red spring wheat market area also on occasion enter the hard red winter wheat market or soft red winter wheat market to purchase wheat because of the profit advantage from blending. It is believed that the blending of hard red spring wheat with hard red winter wheat is a much more common practice than the blending of soft red winter wheat with either of the two. Furthermore, every year large though varying quantities of spring wheat are shipped to the West Coast to blend with white wheat. However, it is not likely that millers in the spring wheat area enter the white wheat market to seek the latter for substitution.

1/ Although the miller is aware of price advantages to be gained through the substitution of one kind of wheat for another he is equally concerned in maintaining a standard uniform product. At times one can expect the flour miller to enter the market for a more desirable wheat in the face of a price disadvantage in an effort to maintain the quality of his product.

To look further, there has been a great change in the wheat situation since the Second World War. The price support extended to the wheat producer and, the government storage plan during the war and postwar period seemed only a temporary solution to an urgent problem. A lack of understanding of the relationships between the different kinds of wheat has limited the effectiveness of wheat price policies, particularly as a guide to wheat producers to provide the various wheats in the proportions desired by the consumers.

Research Problem and the Limitations

This study is designated as part of a regional wheat marketing project undertaken by the Montana Agricultural Experiment Station. It is concerned with the estimation of the price elasticity of hard red spring wheat, the substitution elasticities with other kinds of wheat, and with the implication of these functional relationships to Federal Price Policies for wheat.

The limitations of this study are as follows:

1. The analysis of the elasticities is limited to domestic consumption with the effects of exports, imports, storage and carryover not accounted for. The scale of such a study and inadequacy of the available data precludes such an extension.

2. Domestic consumption is treated as a homogeneous variable under the assumption that consumption is for food only. Various other uses, e.g. feed, seed, and industrial uses, are disregarded.

Objectives of the Study

1. To isolate, analyze, and describe the data which show the historical change over a period of time in price and domestic

consumption of hard red spring wheat and other principal kinds of wheat. This leads to the analysis of the demand structure for hard red spring wheat and relationships with other principal kinds of wheat.

2. To indicate the implications of the above analysis for national price policies for wheat.

Hypothesis

1. The domestic consumption of hard red spring wheat is the function of the price of hard red spring wheat, the price of hard red winter wheat, the price of soft red winter wheat, and the per capita disposable personal income; i.e., a causal relationship exists between the consumption of hard red spring wheat, the price of this kind of wheat, and competing wheats.

2. The knowledge of these relationships is relevant to an appraisal of price policies for wheat.

Procedure

A brief review of the literature was made. Secondary data were collected and are described in Part II. The same Part covers the methods of analysis, the equations, their interpretation, and the shortcomings of this analysis.

Part III briefly discusses the implications of the statistical results as they may be related to various alternative price policies for wheat, and the conclusions.

PART II

THE DATA AND THEIR ANALYSES

Nature of Data

The Period of Time Used

The principle followed in choosing the time period for the analysis was to select a period not longer than necessary to average out the effects of irregularity of the variables, and also, not shorter than needed to insure the operation of a set of homogeneous variables.[1] Domestic consumption of hard spring wheat and the operation of the wheat markets are continuous processes; annual data based on a July-June crop year were used for both domestic consumption and prices.

Annual domestic consumption is the sum of the wheat stocks of the previous year by kinds plus production and imports and, minus exports and carryover.[2] The price of wheat by kinds was the average annual price at the specified terminal market for each kind of wheat.

Per capita disposable personal income was also an annual average.[3] However, it is an annual average for the calendar year rather than the fiscal year.

1/ Richard J. Foote and Karl A. Fox, Analytical Tools for Measuring Demand, Agricultural Handbook No. 64, U.S.D.A., 1954, p. 7.

2/ United States Department of Agriculture, The Wheat Situation, WS-150, U. S. Government Printing Office, Washington, D. C., June 1956, p 12.

3/ United States Bureau of the Census, Statistical Abstract of United States, 1956, Seventy-seventh edition U. S. Government Printing Office, Washington, D. C., 1956.

Years Included

Annual price data of wheat by kinds can be found dating back to 1901, but domestic consumption data of hard spring and other competing wheats can be traced back only to 1929.[1] As many years as possible were included, as well as a sufficiently long period for both prewar and postwar periods. A separate analysis was carried out to see how prewar and postwar relationships compared. Furthermore, abnormal years in which price ceilings were in effect were excluded from the analysis. This analysis covered the period from 1929 to 1955. This period was sufficiently long to cover both the postwar and prewar periods. Separate analyses for the periods 1931 to 1940 and 1947 to 1955 were also made. The years from 1943 to 1946 were omitted from the analysis because of extremely restrictive government price policies.

Prices Used

Terminal market prices were used for wheat by kinds because the main purpose of this study was to measure domestic demand for wheat as largely reflected by the actions of the milling industry.

Hard spring wheat prices were the cash closing prices of ordinary protein, No. 1 dark northern spring wheat in the Minneapolis market; hard winter wheat prices were the cash closing prices of ordinary protein, No. 2 hard red winter in the Kansas City market; soft winter wheat prices

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[1] United States Department of Agriculture, op.cit., September 1943, p. 12.

were the cash closing prices of No. 2 soft red winter wheat in the St. Louis market.[1]

Use of Logarithmic Variables

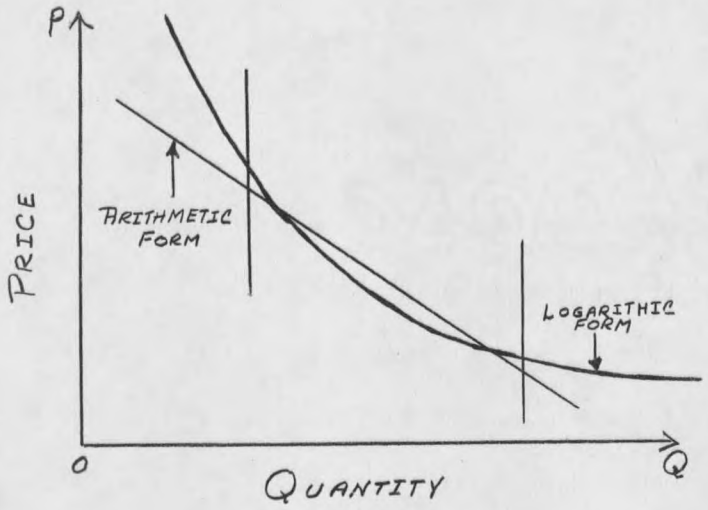
Foote and Fox state that "logarithmic equations have the mechanical advantage of yielding constant elasticity curves and in many analyses they appear to fit the data better than arithmetic relationships . . . Differences between calculated values from arithmetic and logarithmic equations may be fairly small in the interwar period, but an attempt to project the analyses to high postwar price and income levels may reveal strong reasons for selecting the logarithmic form."[2] Since this study was an investigation of price and substitution elasticities and involved a long period covering both prewar and postwar periods, the logarithmic form was considered more appropriate.[3]

If the purpose of this analysis were to make predictions at extreme price and consumption values, the arithmetic type equation would probably be superior. Since this was not the purpose of this investigation, it does not constitute a handicap. This can be shown by the diagram following on the next page.

1/ United States Department of Agriculture, Agricultural Statistics, 1943 - 1955, U. S. Government Printing Office, Washington, D. C.

2/ Richard J. Foote and Karl A.Fox, op.cit., pp. 9-10.

3/ Logarithmic equations have the mechanical advantage of yielding constant elasticity curves and these elasticities are conveniently represented by the coefficients.



The graph above is an arithmetic and geometric representation of a functional relationship between price (P) and quantity (Q). At the medial values the two curves appear to be equally representative, however, there is considerable divergence at the extremities.

The Analysis

The decision as to whether to use a single-equation analysis or a "system of equations" analysis depends on a number of factors. The questions to be asked are these:

1. Is consumer income significantly affected by changes in price or consumption of the given commodity?
2. Is more than one major domestic outlet available for the given commodity?
3. Is consumption of a given commodity significantly affected by storage?

4. Is the analysis designed primarily for use in forecasting and, is it assumed that no change in structure has taken place over the period included in the analysis?

5. If the analysis is designed mainly to estimate the elasticities of demand or other coefficients, are all the independent variables "predetermined" as by weather or by government actions?

A negative answer to the first three questions and a positive answer to the last two would, for all practical purposes, largely preclude the use of any other analytical method except the single-equation approach. Theoretically, disposable income should be treated separately in a complete model of an economic system because it is either directly or indirectly affected by production of all goods and services. For any single given commodity, the answer cannot be definitely given, for it would depend upon the extent to which disposable income is influenced by variations in the consumption and price of the commodity. Therefore, the answer to question 1 is "no" since the proportion of disposable income spent on wheat is very small.

The answer to question 2 again is "no", since the assumption was made in Part I that all the wheat was consumed as food only. Other uses such as for feed, seed, and industrial uses were disregarded.

Question 3 deals with a more complicated situation. Annual domestic consumption of wheat does not equal annual supplies of wheat; an additional equation would be needed for simultaneous solution. However, the large amount of wheat in stock is due mainly to the government price programs. And, actually in the free wheat market, supply and consumption tend to equality. Therefore, the answer is "no."

This study is solely designed for forecasting and there is reason to believe that no change in structure has taken place over the long period, thus the answer to question 4 is "yes." The answer to question 5 is also "yes" because the prices of hard spring wheat and the competing wheats are largely predetermined by the government support program.

Furthermore, the relative merits of the single equation approach and a system of equations approach were discussed at a meeting of the Western Regional Technical Committee on Wheat Prices and Price Policies held in Bozeman, Montana, July 13, 1955. This committee decided that the single equation approach would serve best.[1/]

Notations

The following notations will be used:

1. QHS - The logarithm of the domestic consumption of hard spring wheat in units of one million bushels.
2. QHW - The logarithm of the domestic consumption of hard winter wheat in units of one million bushels.
3. PHS - The logarithm of the cash closing price of ordinary protein No. 1 dark northern hard red spring wheat in units of one cent.
4. PHW - The logarithm of the cash closing price of ordinary protein No. 2 hard red winter wheat in units of one cent.
5. PSW - The logarithm of the cash closing price of No. 2 soft winter wheat in units of one cent.
6. P'Hs - The closing price of lard spring deflated by the index of total disposable personal income in logarithmic form.

1/ See the minutes of the Western Regional Technical Committee on Wheat Prices and Price Policies, Bozeman, Montana, July 13, 1955.

7. P'HW - The closing price of hard winter wheat deflated by the index of total disposable personal income in logarithmic form.

8. P'SW - The closing price of soft winter wheat deflated by the index of total disposable personal income in logarithmic form.

9. DPI - Per capita disposable personal income on 1954 basis in units of one dollar.

Equations

1. 1929-1955 -- $QHS = a + b_1 P'HS + b_2 P'HW + b_3 P'SW$

2. 1929-1955 -- $QHS = a + b_1 PHS + b_2 PHW + b_3 PSW + b_4 DPI$

3. 1931-1940 -- $QHS = a + b_1 PHS + b_2 PHW + b_3 PSW + b_4 DPI$

4. 1947-1955 -- $QHS = a + b_1 PHS + b_2 PHW + b_3 PSW + b_4 DPI$

5. 1929-1955 -- $QHW = a + b_1 PHW + b_2 PHS + b_3 PSW + b_4 DPI$

The equations above are a series of separate multiple regression equations in logarithmic form calculated by using the limited information approach.[1] Equation 1 is the only equation which uses 27 years without taking out the years that were under government price action. For the purpose of comparing equation 1 with the other equations the price variables were deflated by the index of total disposable personal income, 1955 = 100. Equation 2 employs a fourth independent variable, per capita disposable personal income on a 1954 basis[2] and runs from 1929

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[1] Joan Friedman and Richard J. Foote, Computational Methods for Handling Systems of Simultaneous Equations, U.S.D.A., 1955, pp. 3-15.

[2] Dollar estimates in current prices divided by consumer price index on a 1954 basis.

to 1955 but excludes the years 1943 to 1946. Equations 3 and 4 -- 1931 to 1940, and the postwar period, 1947 to 1955 respectively -- employ the same income variable. Equation 5 uses domestic consumption of hard winter as dependent variable and also employs the income variable.

Results

1. 1929-1955

$$QHS = 2.46 - 0.81\ P'HS - 1.42\ P'HW + 1.74\ P'SW$$

S_b = (0.76) (0.89) (0.65)

r^2 = (0.05) (0.10) (0.24)

$R^2 = 0.41$ $S = 0.39$

2. 1929-1955

$$QHS = 0.01 - 0.52\ PHS - 1.53\ PHW + 2.22\ PSW + 0.60\ DPI$$

S_b = (0.70) (1.15) (0.89) (0.41)

r^2 = (0.03) (0.09) (0.26) (0.11)

$R^2 = 0.56$ $S = 0.10$

3. 1931-1940 (Prewar)

$$QHS = 5.36 - 0.55\ PHS + 1.57\ PHW - 1.47\ PSW - 0.82\ DPI$$

S_b = (0.33) (0.70) (0.68) (0.22)

r^2 = (0.36) (0.50) (0.48) (0.72)

$R^2 = 0.85$ $S = 0.035$

4. 1947-1955 (Postwar)

$$QHS = -1.44 - 2.17\ PHS + 4.14\ PHW - 0.49\ PSW + 0.06\ DPI$$

S_b = (1.33) (1.53) (0.10) (0.45)

r^2 = (0.40) (0.65) (0.11) (0.005)

$R^2 = 0.72$ $S = 0.03$

5. 1929-1955

$$QHW = 0.90 - 2.25\ PHW + 0.21\ PHS + 1.88\ PSW + 0.60\ DPI$$

S_b = (0.69) (0.41) (0.53) (0.41)

r^2 = (0.37) (0.45) (0.41) (0.25)

$R^2 = 0.64$ $S = 0.06$

Figures in the top parentheses under each coefficient of regression indicate the respective standard error of estimate, and figures in the bottom parentheses denote the respective partial coefficient of determination.

The Analysis of Coefficients

Price elasticity is a coefficient that measures the percentage change in consumption brought about by a given percentage change in price. It is defined by Alfred Marshall as "the percentage change in quantity taken divided by the percentage change in price when price change is small."[1/] When demand for a product is elastic, i.e. elasticity greater than one, the percentage change in quantity will be greater than the

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1/ Alfred Marshall, Principles of Economics, Eighth Edition, The Macmillan Co., London, 1920, Book III, Chapter IV.

percentage change in price. Conversely, if demand is inelastic for a product, i.e. elasticity smaller than one, then the change in quantity will be proportionally smaller than change in price. In the case of unitary elasticity, i.e. elasticity equals one, the percentage changes in quantity and price will be the same.[1/]

Elasticity of substitution is a coefficient that measures the percentage change in the ratio of the quantities of substitute products consumed to a given percentage change in the ratio of the prices of these products.[2/] In other words, it measures the extent to which these products are related to each other. If products are substitutable for each other, the elasticity will be positive; the elasticity of substitution will be negative for complementary products. The coefficient of regression for independent products will tend to zero.

Income elasticity is defined as the ratio of relative change in quantity to relative change in income.[3/] It measures the change in quantity demanded which would result from 1 percent change in money income when other factors are held constant. It is expressed by a positive, negative or zero sign to indicate the effect of changes.

1/ Richard H. Leftwich, The Price System and Resources Allocation, Rinehart & Co., Inc., New York, 1955 pp. 39-42.

2/ Kenneth W. Meinken, The Demand and Price Structure for Oats, Barley, and Sorghum Grains, U.S.D.A., 1953, p. 34.

3/ George J. Stigler, The Theory of Price, The Macmillan Co., New York, 1956, p. 50.

As indicated by equation 2, the price elasticity for hard spring wheat was -0.52. That is, when the price of hard spring wheat rises 1 percent, the domestic consumption of hard spring wheat will fall 0.52 percent. The demand for hard spring wheat was relatively inelastic in the period of 1929 to 1955. Furthermore, in comparing the prewar period with the postwar period, it was noted that in the years of 1931 to 1940 the demand for hard spring wheat was inelastic, -0.55. However, it was highly elastic in the years of 1947 to 1955, - 2.17. Actually, various analyses have indicated the demand for hard spring wheat is not elastic. A test of the significance of the "b" value was run for all the equations on a null hypothesis that the hypothetical "b" value equaled one. The conclusion was that the occurance of the demand for hard spring wheat being elastic was largely a chance occurrence. Furthermore, the standard error of estimate of the "b" value was large (1.33) and a coefficient that large could easily occur by chance. This also applies to the other "b" values even though, logically, the demand for hard spring wheat is inelastic.

Again, in equation 2, a substitution elasticity of -1.53 for hard spring wheat and hard winter wheat was found. The negative sign of the coefficient of regression showed the complementary nature of these two kinds of wheat. It indicated that when price of hard winter wheat rose 1 percent, it resulted in a decrease of 1.53 percent in the domestic consumption of hard spring wheat. The complementary nature is consistent with equation 1, -1.42. Again, we found the opposite situation in equations 3 and 4. They yielded positive signs for this relation. In

the prewar period, the "b" value for substitution was +1.57 which denoted a competing relationship between hard spring wheat and hard winter wheat, and an even more intense competing relationship in the postwar period, +4.14. However, in equation 5, a coefficient of regression of +0.21 showed an almost independent relation between hard spring wheat and hard winter wheat.

A coefficient of regression with a negative sign denoting complementarity between hard spring wheat and the hard winter wheat is somewhat illogical. However, one explanation would be that they are perfect substitutes.[1/]

A similar situation is revealed by the substitution elasticity for hard spring wheat and soft winter wheat. As indicated by equation 2, the relationship was a highly competing one, +2.22, and it was consistent with equation 1, +1.74.[2/] The situation reversed itself once again. For the prewar period, the complementary nature between the two is indicated by a coefficient of regression of -1.47, and a small figure, -0.49, but still complementary for the postwar period. Meanwhile, equation 4 points to the competing nature of the two wheats with a coefficient of substitution of +1.88

The derived income elasticities gave more consistent results. In general, the sign of an income elasticity should tend to be positive

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1/ See Richard J. Foote and Karl A. Fox, op. cit., pp. 14-15.

2/ The expectation was that the regression coefficient measuring the relationship between the quantity of hard spring wheat and the price of soft winter wheat would approach insignificance in view of the known independent relationship of the two commodities.

because when income increases people are apt to spend more. Certainly, this does not hold for the so-called "inferior foods." Wheat used to be classified as one of the inferior foods, for when incomes increased, people would spend more of their income on food like meat, fruit, etc., and less on wheat. This was borne out by the income elasticity of -0.82 found for the prewar period. However, for the postwar period an income consumption elasticity of +0.06 tended to indicate an absence of a meaningful relationship. In equations 2 and 5, the income elasticity coefficients were postive and identical. One explanation may be that wheat is no longer an inferior food. This can be partially supported by the table below.

TABLE I. FLOUR CONSUMED IN THE UNITED STATES. APRIL-JUNE, 1955, BY INCOME.[a]

	Under $1000	$1000 - $1999	$2000 - $2999	$3000 - $3999	$4000 - $4999	$5000 - $5999	$6000 - $7999	$8000 - $9999	$10000 Over
Household	7.51[b]	5.94	5.32	4.39	3.85	3.82	3.17	3.20	2.67
Commercial	3.46[b]	4.84	6.19	7.58	7.78	8.44	8.61	7.89	8.31
Total	10.97[b]	10.78	11.51	11.97	11.63	12.26	11.78	11.09	10.98

[a] Summed from United States Department of Agriculture, Food Consumption of Household in the United States, U. S. Government Printing Office, Washington, D. C., 1955, Report No. 1. pp. 51-65.

[b] Each unit equals one pound.

The table above shows that when incomes increase, consumption of flour in households declines rapidly. However, this is offset by the fact that when incomes increase, flour consumption by households in the

form of commercially prepared products increases. In total, the changes in consumption of flour are positively related to the changes in income. Though total flour consumption began to fall after $5,000-$6,000 group, it never did fall below the lowest value of 10.97 pounds.

A test of significance of the coefficients of multiple correlation indicated that all were significant at the 99 percent level.

The Shortcomings

First, an approach using the analysis of first differences might have yielded more significant results. Although using actual data has the advantage of measuring the deviations from a long term average, the first different approach is used when emphasis is placed on measuring the factors that affect year-to-year changes.

Second, since the miller does not make the decision to purchase a given kind of wheat with total disregard for the price of other wheats, the use of price ratios rather than actual prices might have yielded more readily the desired results. Furthermore, such a procedure would not have required a deflation of the price series used in the analysis.

PART III

IMPLICATIONS FOR POLICY AND CONCLUSIONS

With the relationships derived in Part II, and with the assumption of constant supplies of all wheats and constant disposable income, an attempt was made to estimate domestic consumption of hard spring wheat under a variety of price support levels.

The support prices used were: (1) the United States Department of Agriculture announced support price for 1957/1958 of $2.00,[1] (2) the support price for 1949/1950 of $1.87,[2] (3) a support price for 1958/1959 of $1.80 and, (4) an assumed support price for 1958/1959 of $1.50.

The following are the tabulated results:

TABLE II. ESTIMATION OF THE DOMESTIC CONSUMPTION OF HARD SPRING WHEAT UNDER VARIOUS SUPPORT PRICES.

Unit = Million Bushel

	Support Price For 1957/1958 ($2.00)	Support Price For 1949/1950 ($1.87)	Assumed Support Price For 1958/1959 ($1.80)	Assumed Support Price For 1958/1959 ($1.50)
Equation 2 1929-1955	213.88	211.47	210.02	203.65
Equation 3 1931-1940	67.37	69.46	70.91	76.72
Equation 4 1947-1955	143.14	131.49	121.86	94.06

1/ United States Department of Agriculture, The Wheat Situation, op.cit., June 1957, Table 4, p. 12.

2/ Schickele, Rainer, Agricultural Policy: Farm Programs and National Welfare, McGraw-Hill Book Co., New York, 1954, pp. 183-184. Calculated by new price parity.

From the above table it can be seen that:

1. Equation 2 gave us an estimated domestic consumption of hard spring wheat in 1957/1958 of 213.88 million bushels under a support price of $2.00 per bushel. Furthermore as the support price was lowered total consumption decreased.

2. Equation 4 indicated a similar relationship as did equation 2.

3. Equation 3, on the other hand indicated an inverse relationship between level of price supports and total domestic consumption of hard spring wheat.

Because of the relative unreliability of the coefficients obtained, and because of the conflicting nature of these coefficients, the study does not appropriately lend itself to an observance of implications for agricultural price policy. However, the analysis does permit the following modest conclusions:

1. Hard spring and hard winter wheats are substitutes, one for the other, in the manufacture of bread flour.

2. The demand for hard spring wheat was price inelastic.

3. The domestic consumption of hard spring wheat is a function of the price of this wheat, competing wheats, and disposable personal income.

APPENDIX