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ANALYSIS OF AGRICULTURAL LIME DEMAND AND SUPPLY RELATIONSHIPS

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Limestone has a long history of use in agriculture. Agricultural lime, commonly termed aglime, is usually in the form of ground or crushed limestone. Its importance to agriculture is recognized by its being considered as a fertilizer, a soil conditioner, and a soil amendment agent correcting soil acidity for improved productivity.

There is a great disparity between the need for and actual use of agricultural lime even though there are proven benefits associated with its application. The returns on investment in agricultural limestone are very high if properly used at its recommended rates. Even though lime efficiency has been proven, U.S. farmers have decreased their use of lime. Factors contributing to a drop in lime usage in agriculture include government policy changes (decrease in government cost share for the purchase of lime used), and changes in farmers' cropping systems (shift away from crop rotations that include a legume forage). The supply of agricultural lime also has been affected by low profit margins for agricultural lime producers, seasonal demand for agricultural lime, the difficulties in its storage by producers, and the requirement of additional crushing operation for a very fine agricultural lime that entails additional operating cost.

Research Objective

The objective of this analysis is to estimate demand and supply relationships that can best explain the observed variation in the usage of agricultural limestone in Ohio. The purpose of the demand equation is to quantify the sensitivity of farmers' demand for agricultural lime with respect to alternative factors such as prices of farm products, agricultural lime, and other inputs. The supply equation is used to estimate the effect of agricultural lime price, prices of key inputs such as transportation and fuel, and prices of non agricultural lime products on agricultural lime supplies.

Data Collection

This study estimates demand and supply relationships for agricultural lime in the State of Ohio. Historic price and quantity data are used to estimate these relationships statistically. The accuracy of these estimates largely depend on the quality of the data. The data and the sources of data collected for the purpose of the present study consist of the following:

- The price of ground limestone in Ohio in dollars per ton was obtained from the Annual Summary of Agricultural Prices, U.S. Department of Agriculture, which records prices paid by farmers (Table 1).

- The quantity of agricultural lime sales in short tons was obtained from sales data published in the Annual Report on Ohio Mineral Industries by the Ohio Division of Geological Survey, Ohio Department of Natural Resources (Table 2). The assumption made here is that the agricultural lime market is a local and regional market, rather than a national market. The quantity of agricultural lime sold by Ohio producers is the same as the quantity used in agriculture by Ohio farmers.

- The price of industrial lime was obtained from the series LIME by the U.S. Department of the Interior, Bureau of Mines.

- Ohio net farm income data were collected from the Ohio Farm Income Series published by the Ohio Agricultural Research and Development Center, Wooster, Ohio (Table 3).

- Price indices for inputs used by agricultural limestone suppliers were obtained from the 1990 Economic Report of the President, Council of Economic Advisors (Table 4).

- Price indices for items used in farm production and for products sold by farmers were obtained from the Annual Summary of Agricultural Prices series, published by the U.S. Department of Agriculture, and from the Council of Economic Advisors (Table 5).

When statistically estimating the supply and demand relationships, all prices are expressed in real terms, deflated by the producer price index for intermediate goods with 1982 as the base year. Ohio net farm income is deflated by the GNP implicit price deflator (base year =1982). The data used to estimate the demand equation for agricultural lime are from 1955 to 1989, and those used to estimate supply are from 1963 to 1989, because of the unavailability of data on industrial lime from 1955 to 1962.

Industry Structure in the United States

The agricultural lime industry is a subsector of a larger lime industry and the crushed stone industry. The United States is the largest producer of crushed stone among the market economy countries. In 1989, total production of crushed stone reached 1.2 billion short tons of which 75 percent was limestone and dolomite. Agricultural lime accounted for 2 percent of total limestone production and 6 percent of total dolomite production. Of 1989 total U.S crushed stone production, 74 percent was from two major geographic areas, the south and the middle west. In the United States, limestone is produced in all states except Delaware, Louisiana, New Hampshire, and North Dakota.

The 1989 crushed dolomite output was reported in 27 states by 92 companies at 136 quarries. Of the 49 million tons of crushed dolomite consumed, 6 percent was used as agricultural lime. The United States is self sufficient in crushed stone of which agricultural lime is a part. Production of limestone meets all domestic demand.

Market Structure of Agricultural Limestone

The agricultural lime industry is characterized by its low unit value. Agricultural limestone is a material of low price at the point of production; however, transportation costs substantially increase price at the point of delivery. Consequently, agricultural lime generally is produced near its marketable area and points of use, and the industry is mostly concentrated in high demand areas.

The limestone industry is highly competitive and characteristically serves local or regional markets as a result of an abundance of mineral deposits. Factors affecting production are mainly labor, equipment, energy, water, and compliance with environmental and safety regulations. These factors affect the cost of production which can vary with the natural formation of deposits, their geographic locations, and the quality and kind of product. The closer the markets are to the supply areas, the more significant the advantage to producers. Therefore, local production even though impure or of lower grade is more economical to farmers than purchasing higher quality material from distant markets at a higher cost. Most producers of agricultural lime are relatively small and face competition from large companies producing agricultural lime as a joint product of limestone or industrial lime production.

Limestone and dolomite were produced or sold by 80 companies at 122 operations in 54 Ohio counties during 1990. Total sales of limestone and dolomite were 52.7 million short tons from which 37.2 percent was the contribution of 5 counties: Erie, Franklin, Wyandot, Ottawa, and Sandusky. The 1990 reported sales of agricultural crushed and broken limestone accounted for 3 percent of total limestone sales in the state (Ohio Department of Natural Resources).

Agricultural limestone producers, which are mainly crushed stone producers, face some problems related to environmental regulations, transportation costs, and marketing programs. Location of firms and processing quarries near suburban areas make air pollution from the crushing operation a major problem in the crushed stone industry. On the marketing side, in addition to the competition of the fertilizer industry, little effort has been made to promote the sale of agricultural limestone.

Method of Estimation

A simultaneous system of equations, estimated by a two-stage regression technique, is used to estimate factors influencing demand and supply of agricultural lime. Because demand and supply are believed to be determined simultaneously, Two Stage Least Squares (TSLS) estimation technique is applied. This is to avoid biasedness and inconsistency associated with Ordinary Least Squares (OLS) estimators. Indeed, OLS estimation is inappropriate when there is joint determination between two or more dependent variables. The following assumptions are made:

- demand and supply (quantity and price) of agricultural lime are simultaneously determined. That is, quantity and price of agricultural lime depend on factors affecting demand and those affecting supply, and the use of agricultural lime related to economic forces that affect the supply as well as the demand side.

- the price of agricultural lime is determined with regard to economic phenomena related to its manufacturing, processing, and marketing. Price is considered as an endogenous variable, defined as being a variable having an effect on the system being studied and also affected by the system.

Results

Two functional forms were used to estimate the model: one with linear equations and one composed of equations with logarithms of the same variables of the first equations, called a double-log linear regression model. The model that offers the better explanation of the demand and supply of agricultural lime is the double logarithmic and only these results are presented. The equations from the TSLS estimation process are the following:

Demand and Supply Estimates

Demand Equation

$$\log(QAL) = \underset{(-1.639)}{-1.9417} \underset{(-0.271)}{- 0.101 \log(PAL)} + \underset{(4.764)}{1.176 \log(IPP)}$$

$$+ \underset{(1.992)}{0.118 \log(NFI)} \underset{(-3.730)}{- 0.677 \log(IIP)} + \underset{(3.251)}{0.539 D}$$

$R^2 = 0.77$ and Adjusted $R^2 = 0.73$

Supply Equation

$$\log(QAL) = \underset{(0.063)}{0.1468} + \underset{(1.557)}{0.646 \log(PAL)} \underset{(-0.025)}{- 0.014 \log(PIL)}$$

$$\underset{(-2.932)}{- 2.234 \log(ITR)} \underset{(-1.179)}{- 0.349 \log(IFU)} + \underset{(2.712)}{2.264 \log(IME)}$$

$R^2 = 0.58$ and Adjusted $R^2 = 0.48$

where

QAL = quantity of agricultural limestone
PAL = price of agricultural limestone
IPP = index of price received by farmers for crops
NFI = real Ohio net farm income
IIP = index of price paid for farm inputs
D = government program variable; 0 = no government program,
1 = government program.
PIL = real price of industrial lime
ITR = price index for transportation equipment
IFU = price index for fuel
IME = price index for material used in manufacturing

Coefficients preceding the variables identify the estimated percent change in the quantity of agricultural lime demanded or supplied associated with a one percent change in the variables. Numbers in parentheses below these coefficients are standard errors of these estimates.

Considering the demand side, in terms of explanatory power, the squared coefficient of determination (R^2) is very high (0.77) indicating that 77 percent of the variation in demand for agricultural lime is explained by the model. Also, the coefficient of determination (R^2) in the supply estimation indicates that the model has an appreciable explanatory power.

The estimated demand and supply relationships identify the contribution of individual factors (say price of agricultural lime, PAL) in explaining the variations in the quantity of agricultural lime demanded or supplied, holding all other variables constant.

The demand price elasticity of agricultural lime is inelastic (-0.101); in this case, inelasticity implies that demand is relatively insensitive to price changes. There is a negative association between the price of agricultural lime and its purchase by farmers; as agricultural lime price increases by 1 percent, quantity demanded by farmers decreases by 0.101 percent. Lime usage proves to be income inelastic (0.118) but highly elastic with respect to crop prices paid to farmers (1.176). That is, a 1 percent increase in net farm income increases quantity demanded by 0.118 percent, while a 1 percent increase in crop prices increases quantity demanded of agricultural lime by 1.176 percent. On the other hand, lime application in agriculture is inversely related to prices of other farm production inputs, and a 1 percent increase in the price of items used for production (IIP) decreases the demand for agricultural lime by 0.68 percent. Last, on the demand side, cost share conservation programs have had a significant positive effect on agricultural lime usage.

The supply price elasticity of agricultural limestone is considered inelastic (0.646). That is, agricultural lime producers respond to a 1 percent increase in agricultural lime price by increasing agricultural lime production by 0.646 percent. An inverse relationship between prices of industrial lime and the supply of agricultural lime is estimated. That is, increasing industrial lime prices result in slightly lower agricultural lime supplies. One percent increase in prices of transportation equipment and fuel leads respectively to a drop of 2.23 and 0.34 percent in lime supply. However, one percent increase in the price of material used in manufacturing increases agricultural lime supply by 2.264 percent, reflecting the fact that increases in manufacturing material prices is associated with increased supply of crushed limestone and a corresponding increase in the agricultural lime by-product.

From the results of this econometric model of agricultural lime supply and demand relationships, the price elasticity of demand is 0.10, and a rise in the price of agricultural lime, holding everything constant, has only a small direct effect on its use. However, the use of agricultural lime is affected by prices of other farm inputs, by net farm income, and by crop prices. An elasticity of supply of 0.64 roughly means that a 10 percent increase in price of agricultural lime would lead producers to increase supply by 6 percent.

The industry appears to be capable of readily increasing supply in response to agricultural lime price increases. This analysis supports the comment by William L. Carter, NCSA's President, who mentioned at the 1980 National Limestone Conference that the crushed stone industry is able to meet the demand side for agricultural lime in a range between 30 million tons and 90 million tons, which are respectively the historic annual use of agricultural lime and the estimated annual need for lime in agriculture.

Summary and Implications

Agricultural lime is a product of both the crushed stone industry and lime industry. It is a material of low price per ton at point of production. However, due to its bulk, transportation costs constitute a considerable part of its price at points of delivery. Because of high transportation costs and the abundance of limestone deposits in the United States, agricultural limestone is marketed within small geographic areas and not transported large distances.

Agricultural limestone has experienced a declining market in agriculture even though the benefits from its application are known to be promising. A two stage model is used to analyze the demand and supply forces of this input market. The double-log linear model is used to estimate these relationships. This model shows that the demand for lime is inelastic with respect to its price. Lower agricultural limestone prices will have only slight impact on increasing its usage. Its use also is affected by the prices of other agricultural inputs used in production. Most importantly, its demand is affected by crop prices. Substantial increases in agricultural lime demand might occur if crop prices were to increase. The quantity of agricultural lime supplied is also inelastic with respect to its price. It is affected by various factors of production such as transportation and fuel costs, which

have an inverse relationship with respect to lime supply. Results of this study indicate that the supply of agricultural limestone is enhanced by increased prices for crushed limestone, but increases in the price of industrial lime dampen the supply of agricultural lime.

If flue gas desulfurization scrubbers are used by electric utility companies, FGD by-product promises to be an effective substitute for agricultural lime, and characteristics of the agricultural lime market will affect FGD by-product use. This new product will be entering a highly competitive market. If it is to be used in agriculture, it will have to replace agricultural lime. Agricultural limestone producers stand to lose market opportunities with the introduction of FGD by-products. However, limestone producers would probably gain an even bigger market if coal burners are retrofitted with scrubbers. The amount of limestone products used in the FGD technology would far exceed the amount of the agricultural lime market replaced by the FGD by-product.

This analysis has implications for agricultural limestone producers under the scenario of expanded market opportunities with the adoption of FGD technology. This analysis estimates the price elasticity of supply to be inelastic (.646). Thus increases in demand would result in proportionately large increases in price. If electric utilities adopt FGD technology, the industry can expect to produce a larger volume of output and receive higher prices.

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Table 1. Price Paid by Farmers for Ground Limestone in Dollars per Ton

Year	Actual Price	Real Price 1982 = 100
1955	4.20	14.70
1956	4.34	14.65
1957	4.46	14.71
1958	4.57	15.03
1959	4.62	15.00
1960	4.66	15.12
1961	4.67	15.25
1962	4.75	15.52
1963	4.74	15.43
1964	4.76	15.45
1965	4.60	14.74
1966	4.65	14.53
1967	4.50	13.91
1968	4.60	13.93
1969	4.60	13.48
1970	4.90	13.84
1971	4.50	12.23
1972	4.20	10.90
1973	4.50	10.61
1974	5.70	10.85
1975	6.40	10.03
1976	5.00	8.21
1977	7.64	11.72
1978	8.30	11.94
1979	8.90	11.35
1980	9.67	10.70
1981	10.50	10.64
1982	10.90	10.90
1983	10.30	10.23
1984	10.60	10.24
1985	12.10	11.75
1986	12.60	12.71
1987	12.70	12.51
1988	12.90	12.04
1989	12.70	11.33

Source: Annual Summary Agricultural Prices, U.S. Department of Agriculture.

Table 2. Agricultural Limestone Sales Report of Crushed and Broken Limestone State of Ohio

Year	Total Quantity (Million Short Tons)
1955	2.2743
1956	2.2457
1957	2.3517
1958	1.8303
1959	1.9289
1960	2.1023
1961	2.0835
1962	1.9514
1963	2.1918
1964	2.1534
1965	1.9355
1966	2.1328
1967	2.0458
1968	1.8775
1969	1.5918
1970	1.5082
1971	1.6251
1972	1.1956
1973	1.5852
1974	1.7353
1975	1.8918
1976	2.1893
1977	1.4211
1978	1.4293
1979	1.3039
1980	1.7585
1981	1.3928
1982	1.2034
1983	1.1183
1984	1.6756
1985	1.2342
1986	1.0787
1987	1.3070
1988	1.4923
1989	1.5621

Source: Annual Report on Ohio Mineral Industries, Department of Natural Resources.

Table 3. Ohio Farm Income

Year	Actual Total Net Farm Income (Million $)	Deflated Total Net Farm Income (Million $)
1955	368.50	1352
1956	369.30	1314
1957	309.00	1062
1958	375.20	1263
1959	374.70	1232
1960	326.70	1057
1961	369.60	1185
1962	333.40	1045
1963	323.30	998
1964	322.80	981
1965	397.10	1174
1966	552.30	1578
1967	385.90	1074
1968	422.80	1121
1969	411.90	1035
1970	404.50	963
1971	418.90	943
1972	564.80	1215
1973	778.20	1572
1974	727.30	1347
1975	711.90	1200
1976	644.00	1021
1977	640.00	951
1978	655.40	908
1979	886.80	1128
1980	611.90	714
1981	310.40	330
1982	476.40	476
1983	120.50	116
1984	915.90	850
1985	867.00	782
1986	819.00	720
1987	956.20	814
1988	766.60	632
1989	823.30	652

Source: Ohio Farm Income Series.

Table 4. Price Indices

Year	Trans-portation	Processed Fuel	Capital Equipment	Material and Components for Manufacturing
1955	34.30	15.80	27.40	30.50
1956	36.30	16.30	29.50	32.00
1957	37.90	17.20	31.30	32.70
1958	39.00	16.20	32.10	32.80
1959	39.90	16.20	32.70	33.30
1960	39.30	16.60	32.80	33.30
1961	39.20	16.80	32.90	32.90
1962	39.20	16.70	33.00	32.70
1963	38.90	16.60	33.10	32.70
1964	39.10	16.20	33.40	33.10
1965	39.20	16.50	33.80	33.60
1966	39.20	16.80	34.60	34.30
1967	39.80	16.90	35.80	34.50
1968	40.90	16.50	37.00	35.30
1969	41.70	16.60	38.30	36.50
1970	43.30	17.70	40.10	38.00
1971	45.70	19.50	41.70	38.90
1972	47.00	20.10	42.80	40.40
1973	47.40	22.20	44.20	44.10
1974	51.40	33.60	50.50	56.00
1975	57.60	39.40	58.20	61.70
1976	61.20	42.30	62.10	64.00
1977	65.20	47.70	66.10	67.40
1978	70.00	49.90	71.30	72.00
1979	75.80	61.60	77.50	80.90
1980	83.10	85.00	85.80	91.70
1981	94.60	100.60	94.60	98.70
1982	100.00	100.00	100.00	100.00
1983	102.20	95.40	102.80	101.20
1984	104.10	95.70	105.20	104.10
1985	106.40	92.80	107.50	103.30
1986	109.10	72.70	109.70	102.20
1987	111.70	73.30	111.70	105.30
1988	113.10	71.20	114.30	113.20
1989	116.10	76.50	118.70	118.20

Source: The Economic Report of the President, Council of Economic Advisors, 1990.

Table 5. Price Indices

Year	Prices Paid for Items Used in Farm Production	Crop Prices Received by Farmers
1955	28.30	53.00
1956	28.20	54.00
1957	29.00	52.00
1958	29.80	52.00
1959	30.00	51.00
1960	29.90	51.00
1961	30.00	52.00
1962	30.50	54.00
1963	30.80	55.00
1964	30.50	55.00
1965	31.20	53.00
1966	32.20	55.00
1967	32.40	52.00
1968	32.90	52.00
1969	34.30	50.00
1970	35.40	52.00
1971	37.40	56.00
1972	39.50	60.00
1973	47.80	91.00
1974	54.30	117.00
1975	59.60	105.00
1976	63.10	102.00
1977	65.30	100.00
1978	70.90	105.00
1979	81.10	116.00
1980	90.20	125.00
1981	96.40	134.00
1982	100.00	121.00
1983	99.70	128.00
1984	101.60	138.00
1985	98.60	120.00
1986	94.20	107.00
1987	96.40	106.00
1988	102.80	124.00
1989	108.10	134.00

Source: Annual Summary Agricultural Prices and The Council of Economic Advisors, 1990.