Alfalfa Seed Demand Analysis Using Panel Data from Seven Western States

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Price responsiveness of alfalfa seed demand is estimated using a panel data set of seven Western states, covering the period 1950 to 1992. The demand function is derived from a generalized Leontief variable cost function with a time trend. Tests are performed and corrections are made for heteroskedasticity and serial autocorrelation. Estimated own-price elasticities of demand are highly inelastic, but over time become price sensitive. The estimated cross-price elasticities indicate that machinery price has the highest impact on alfalfa seed demand. An estimate of technological change indicates that the industry has been taking advantage of the improved seed genetics.
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Introduction

Over the last 20 years acreage used for alfalfa and alfalfa mixtures production has declined. During the same period, however, the US production of alfalfa hay has not changed and has maybe even increased, indicating an upward trend in yield. This increase can be accounted for by changes in cultural practices and seed genetics over time. It is not the purpose of this article to determine which of the reasons explain the yield increase, but rather to examine the demand structure of the alfalfa seed industry.

One of the important inputs in alfalfa hay production is alfalfa seed. According to Nevada enterprise budgets, the amortized cost of replacing an acre of alfalfa is around $30, which in relation to per acre total alfalfa hay cost of $421, is about 7%.[1] Relative to new planting cost, alfalfa seed accounts for about 28%. So although seed is a large cost in terms of replacing an alfalfa hay field, over the life of the stand, seed cost is relatively small. Since the mid-1950s seed production has been gradually decreasing, which is reasonable given alfalfa hay acreage. During the same period, seed production has been shifting to the Western United States, where currently almost all of US production takes place. Most of the certified and proprietary alfalfa seed is

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grown under contract, and multiple year contracts are quite common. This allows the seed companies to exercise some control on the quantity of seed marketed every year.

The relationship between alfalfa seed price and quantity demanded is of interest to both seed companies and seed growers. To keep the growers interested in seed production and still make a comfortable profit, the seed companies would want to understand price relationships. Moreover, given that one of the purposes of the seed contract is to control acreage, input substitution elasticities are also of considerable interest to the seed companies. Additionally, there is interest by seed companies and farmers as to whether changing seed genetics has impacted yields. Farmers are also interested in knowing whether the additional cost of using certified seed is economical, and seed companies would like to know whether resources should be put into alfalfa seed development. The above considerations indicate the need for and importance of an economic analysis explaining the price relationships in alfalfa seed production. To our knowledge there have been no economic analyses conducted on alfalfa seed demand. This article attempts to bridge that gap.

In this article we mainly focus on two important aspects of alfalfa seed production: the price responsiveness of alfalfa seed demand and the impact of disembodied technological change on alfalfa seed demand. For this empirical study, panel data are used that cover 43 years in seven western states. Based on a behavioral assumption of cost minimization on the part of alfalfa hay growers, a derived demand function for alfalfa seed is obtained using a generalized Leontief (GL) cost function. Based on econometric tests, both heteroskedasticity and autocorrelation corrections are performed in a panel data context. The price responsiveness of the derived demand function is then explained in terms of various elasticities.

For estimation of the input demand function we use four variable factors of production and one quasifixed factor. The four variable factors are seed (s), energy (e), farm machinery (m), and labor (l); and the quasifixed factor is land (H). A variable related to chemical use was not included. Fertilizer use across the western states is quite variable, particularly once a stand is established. We also felt that at least some of the affect of fertilizer would be accounted for by the energy variable. Use of herbicides and insecticides is minimal. The prices of the variable factors are w_s, w_e, w_m, and w_l. A panel data set (meaning time series and cross-sectional data are combined) of seven western states covering the period 1950 to 1992 were used to estimate the derived demand function. The states included are California, Idaho, Montana, Nevada, Oregon, Utah, and Washington. Quantity of seed demanded was estimated from production data taken from *Agricultural Statistics* (USDA 1950–1972),[2] Seed Crops (1972–1982),[3] and the Field Seed Institute of North America[a] (1982–1992). The quantity of alfalfa and alfalfa mixtures, as well as acreage, was taken from *Agricultural Statistics* (USDA).[2] The price used for alfalfa seed ($/100 lb) was noncertified alfalfa seed prices paid by farmers taken from *Agricultural Statistics*.[2] Diesel fuel price ($/gal) was used as a proxy for energy and was gathered from the *Agricultural Price Annual Summary* (USDA).[4] The price of labor was the hourly wage of field and livestock farm workers and was gathered from the *Farm Employment and Wage Rate* publication (USDA).[5] The price of farm machinery is an index of other machinery obtained from *Agricultural Prices* (USDA).[6]

The equation used for estimating alfalfa seed demand is

$$x_s = \mu_f + Y\left[\begin{array}{c}\alpha_{ss} + \alpha_{se}\left(\dfrac{w_e}{w_s}\right)^{0.5} + \alpha_{sm}\left(\dfrac{w_m}{w_s}\right)^{0.5} \\ + \alpha_{sl}\left(\dfrac{w_l}{w_s}\right)^{0.5} + \beta_{it}t^{0.5} + \gamma_{it}t\end{array}\right] + Y^{0.5}[\beta_{ih}H^{0.5} + \gamma_{ith}t^{0.5}H^{0.5}] + \gamma_{ith}H + e, \quad (1)$$

where x_s is the demand for alfalfa seed and e is the random error term. The subscripts e, m, and l rep-

[a]The Field Seed Institute of North America is a private company that collects production data from seed companies. The Institute provided data from 1982 because the USDA quit collecting alfalfa seed production data in 1982.

resent the three variable inputs of energy, machinery, and labor, respectively; μ_i are dummy variables for each state in the study. The α, β, and γ are parameters to be estimated. The subscripts i and t indicate states and time, respectively. A nonlinear regression program was used to estimate the derived demand function.

Because actual seed demand data is not available, seed demand was estimated by calculating a 5-year moving average of aggregate alfalfa seed production to total alfalfa hay production. The reason for using the moving average is to washout the effect of any seed carryover and develop the ratio of pounds of seed used to produce 1 ton of alfalfa hay. The ratio was taken times hay production of each period and each state to get seed demand. In doing this, we assume that total production of alfalfa seed will be equal to its total demand in the long run. This also implicitly assumes that there is no difference between states in terms of alfalfa seed requirements per unit of alfalfa hay.

Table I. Parameter Estimates for Alfalfa Seed Derived Demand Model.

Estimates	Value	t Statistic
$\hat{\mu}_1$	−0.331	−3.916
$\hat{\mu}_2$	−0.390	−4.225
$\hat{\mu}_3$	−0.404	−4.467
$\hat{\mu}_4$	−0.219	−2.532
$\hat{\mu}_5$	−0.388	−4.028
$\hat{\mu}_6$	−0.259	−3.645
$\hat{\mu}_7$	−0.681	−4.846
$\hat{\alpha}_{ss}$	−2.768	−1.876
$\hat{\alpha}_{se}$	0.038	0.355
$\hat{\alpha}_{sm}$	0.202	0.734
$\hat{\alpha}_{sl}$	0.409	1.949
$\hat{\beta}_{it}$	0.716	2.661
$\hat{\gamma}_{it}$	−0.042	−4.461
β_{ih}	4.848	2.967
$\hat{\gamma}_{ith}$	−0.691	−3.425
$\hat{\gamma}_{ih}$	−0.488	−1.313

Order of state dummy variables: Montana, Idaho, Utah, Nevada, Washington, Oregon, and California.

Results

The estimated parameters are reported in Table I. All but three of the parameter estimates were statistically significant at the 5% level of significance. A general linear F test on the dummy variables indicates that not all parameter estimates of the state dummy variables are statistically equal, meaning that the levels of the derived demand functions of the states are different. This difference would be expected, given geographical and climatic differences affecting alfalfa growth.

Own-price and cross-price partial elasticities, calculated at the sample mean of the data for each state, are reported in Table II. Own-price elasticities (E_{ss}) for seed were consistent across states and were very inelastic (meaning that demand is not particularly sensitive to changes in price) as would be expected for a low cost input of a perennial crop. Small inelastic demand is fairly common for agricultural commodities, which simply indicates that the quantity demanded does not change very much with changes in price.

The cross-elasticity of alfalfa seed demand with respect to the price of machinery, E_{sm}, indicates that as the price of machinery goes up, the quantity of alfalfa seed demanded increases, which further means the price of alfalfa seed will decrease. That is, machinery and seed are found to be substitutes. It may also be stated that more use of machinery in alfalfa hay production reduces the demand for alfalfa seed. For a 1% rise in machinery price, the quantity of alfalfa seed demand increases by 0.2% on average, indicating a very inelastic cross-price effect. Among the seven states, the mean E_{sm} is found to be the highest for Montana and Nevada and least for California. An explanation of this result is not entirely obvious, but perhaps one explanation is related to stand life. Although we do not have data available to verify the claim many farmers have indicated to us that the period of time a stand of alfalfa is kept in production is decreasing. The reason they give is that the price differential for hay quality is such that it is economical to replace the stand more frequently in order to maintain quality. Machinery prices have been increasing, but the machinery that is purchased is not the same as being replaced. Machinery tends to be big-

Table II. Elasticities by State.

State	E_{ss}	E_{sm}	E_{sl}	E_{se}	E_{sH}	E_{st}
Montana	−0.23	0.21	0.018	0.0079	0.198	−1.04
Idaho	−0.21	0.19	0.017	0.0073	0.175	−0.39
Utah	−0.23	0.20	0.019	0.0079	0.179	−0.41
Nevada	−0.24	0.21	0.019	0.0082	0.191	−0.36
Washington	−0.22	0.19	0.019	0.0074	0.185	−0.40
Oregon	−0.21	0.19	0.018	0.0072	0.183	−0.37
California	−0.21	0.18	0.019	0.0071	0.145	0.18

ger and faster, and so the new machine will cover more acres in a given time period. Thus, given that acreage is declining and the fact that machinery covers more acres per period of time, it seems reasonable that less machinery will be required to produce alfalfa. Alternatively, the increase in stand replacement results in increased use of seed. Whether or not this trend will continue will depend, in part, on the alfalfa hay market in terms of price differentiation due to quality. Certainly new technology that would increase the accuracy of nutrient testing would enhance this trend. There is some indication that in some parts of the country farmers are decreasing the amount of seed per acre that is being used in planting. While this trend may be true, apparently the quantity demanded due to reduced stand life is playing a more important role.

The responsiveness of demand for seed due to a change in the price of labor and energy are found to be positive, but almost zero. This indicates a very low or negligible substitutability between seed and these two factors for all seven states. The estimated cross-price elasticities indicate that among the variable inputs (i.e., machinery, labor, and fuel), machinery price has the highest impact on the quantity demand for alfalfa seed for all seven western states.

The elasticity of intensity measures the responsiveness of alfalfa seed quantity demand to a change in the quasifixed input, land. This is represented by E_{sH} in Table II. The results indicate that when hay acreage decreases, the quantity of seed demand will decrease and the price of seed will increase. The estimated elasticities are highly inelastic and there is not much variation across states. However, the E_{sH} is highest for Montana followed by Nevada and least for California. For Montana, Nevada, Washington, and Oregon the elasticity of intensity is higher than the average, which is 0.18.

The change in demand for seed with respect to time is a measurement of disembodied technology change, E_{st} (Table II). Except for California, estimates indicate that less seed is used to produce the same amount of hay over time. And, even for California, the coefficients when calculated by year indicate that technology has been seed saving since the mid-1970s. We really have no explanation for this latter phenomenon. The value for Montana appears to be high relative to the other states. It is interesting to note that all states, including California, have experienced the seed saving technological progress. Undoubtedly the more efficient use of seed is due to technology changes related to cultural practices, as well as genetics. Some alfalfa experts we talked to indicate that in some parts of the United States the seeding rate has been declining. Alternatively, according to Nevada records, the seeding rate has not changed during the last 20 years; this seems to be the case for some other states where enterprise budgets are available. In this case, it would seem that changes in genetics accounts for much of the technology change.

Given panel data, the change in the estimated price responsiveness over time can be examined. The own-price and cross-price elasticities, elasticity of intensity, and the impact of technological change over time for all seven states are calculated and reported in Table III at a 5-year interval. It is clear from the second column of the table that although the own-price elasticity of alfalfa seed has remained inelastic throughout the period of our study, it has

Table III. Elasticities over Time for Selected Years.

Years	E_{ss}	E_{sm}	E_{sl}	E_{se}	E_{sH}	E_{st}
1950	−0.100	0.087	0.009	0.004	0.415	3.555
1955	−0.107	0.093	0.010	0.004	0.238	0.514
1960	−0.132	0.116	0.012	0.004	0.234	0.085
1965	−0.168	0.147	0.015	0.005	0.221	−0.108
1970	−0.220	0.194	0.020	0.007	0.202	−0.039
1975	−0.201	0.177	0.018	0.007	0.142	−0.583
1980	−0.300	0.262	0.025	0.012	0.105	−0.887
1985	−0.489	0.434	0.038	0.017	0.032	−1.532
1992	−0.384	0.341	0.032	0.011	−0.018	−1.286

become more price sensitive over time. The estimated value of the elasticity, E_{ss}, increased almost by 4 times between 1950 and 1987. After 1987, a falling trend is noticed. The increase in price elasticity means that changes in production will result in greater price changes than occurred in years past; and if there is a desire for more stable prices, the industry will work toward stricter control of production.

The trend of elasticity of seed demand with respect to machinery price E_{sm}, remained inelastic throughout the time period of our study, but the degree of substitution monotonically increased until 1987. Energy and labor remained substitutes for seed for the entire time span of our study, and the degree of substitution increased over time.

A falling trend is indicated by the elasticity of intensity, E_{sH}, meaning that over time the quantity of seed required for a given increase in quantity of land has declined. For the first 5 years of our panel the E_{sH} fell rapidly, dropping from 0.41 in 1950 to 0.21 by 1957. After a brief rise during the late 1950s and early 1960s, the E_{sH} continued to fall monotonically. One explanation for the results is that producers over time have found that they could maintain yield and quality while using lower seeding rates. The reason for this could be a better quality seed in terms of germination rates, for instance, or disease resistance of new plants or even improved planting procedures. Again we do not have data to support this explanation other than witness by farmers and seed specialists. Another explanation for such a decline could be genetic improvement in seed quality. This becomes clear when we look at the time trend of the estimated rate of technological change, E_{st}. From the mid-1960s, alfalfa growers in all seven states have experienced positive technological progress; given everything else held constant, over time seed requirement for producing a given level of output has diminished. For the first 12 years of our study, although the estimated E_{st} are found to be positive, indicating a seed using technology, the E_{st} values fell monotonically and rapidly. Although not shown in the table, there were actually a couple of years in the late 1980s when technological change had again become seed using. However, starting from 1989 the effect of technological change became seed saving again. In general, the effect of technological change was seed saving during the period of our study, indicating improvement in the quality of alfalfa seed.

Conclusion

In this study we examined the demand structure for alfalfa seed. Alfalfa seed development, while at one time the domain of university researchers, was taken over by private companies during the 1970s and 1980s. Currently alfalfa farmers have perhaps hundreds of varietal choices that have differing production characteristics. Seed production is a relatively high cost enterprise, and so seed companies, as well as producers, are interested in knowing the characteristics of the variables effecting demand. Results indicate that the quantity of demand for alfalfa seed has become more price sensitive over time, although still inelastic, indicating increasing degrees of substitutability between other variable inputs and seed. It also means greater price variability, given changes in production levels. A time trend clearly indicates that technological change has made alfalfa production seed saving. Because alfalfa acreage is declining and given the trend for seed saving technological change, the seed companies are facing a marketing challenge that could very well effect grower contracts.

Appendix

Demand Relationship

We assume that an alfalfa seed grower minimizes short-run variable cost. This behavior assumes that, given the level of alfalfa hay output and the prices of variable inputs, the growers determines the level of inputs that will minimize the variable production cost. This production behavior can be approximated in terms of a short-run variable cost function as

$$C_{ft} = C(W_{ft}|H_{ft}, t_{ft}, Y_{ft}), \qquad \text{(A.1)}$$

where C is the variable cost; W is a n-dimensional vector of the prices of variable factors X; and H, t, and Y are scalar quasifixed input, an index of technological change represented by the time trend, and scalar output, respectively. The f and t subscripts index states and time, respectively. The cost function (A.1) shows the minimum cost required in state f at time t to produce the given level of output Y with variable factors X and quasifixed input H. For empirical estimation of the assumed production behavior, we need to express the above cost function in terms of a functional form that would reflect the underlying production technology. We use a GL variable cost function that is a twice continuously differentiable nonlinear flexible functional form homogeneous in input prices W.[7,b] One attractive feature of the GL function is that it does not impose a priori restrictions on the sizes and the signs of the elasticities of substitutions. Following Parks,[8] a GL variable cost function augmented to allow for time trend (disembodied technological change) can be expressed as[c]

$$C(W,Y,t,H) = Y\left[\sum_i\sum_j \alpha_{ij} w_i^{0.5} w_j^{0.5} + \sum_i \beta_{it} w_i t^{0.5} + \sum_i \gamma_{it} w_i t\right] \qquad \text{(A.2)}$$
$$+Y^{0.5}\left[\sum_i \beta_{ih} w_i H^{0.5} + \sum_i w_i \gamma_{th} t^{0.5} H^{0.5}\right] + \gamma_h \sum_i H,$$

where w is variable factor price; i and $j = 1, \ldots, N$ index the variable inputs; and α, β and γ are parameters to be estimated. Symmetry and homogeneity conditions are imposed on the cost function. If all α_{ij}, $i \neq j$ are constrained to be nonnegative, then the cost function becomes globally concave. However, these constraints are too restrictive to be useful in practice because they rule out the complementarity between all pairs of inputs. (See Diewert and Wales for the properties of a GL cost function.)

Given Eq. (A.2), the constant output derived demand function for variable input x_i can be obtained using the Shephard lemma, $\partial C/\partial w_i = x_i$, as

$$x_i = Y\left[\sum_{j\neq 1}\alpha_{ij}\left(\frac{w_j}{w_i}\right)^{0.5} + \beta_{it}t^{0.5} + \gamma_{it}t\right] \qquad \text{(A.3)}$$
$$+Y^{0.5}\left[\beta_{ih}H^{0.5} + \gamma_{th}t^{0.5}H^{0.5}\right] + \gamma_h H,$$

where the subscript h refers to the quasifixed input. The conditional derived demand function (A.3) is homogeneous of degree zero in input prices with symmetric cross-price effects. The input demand function indicates the minimum amount of the ith input required to produce a given level of alfalfa output Y that would minimize variable cost C of a typical alfalfa producer. How an alfalfa producer's demand for alfalfa seed would change for a change in its own-price and/or prices of any other variable input and quantity of quasifixed inputs can be examined by calculating the elasticities of the alfalfa seed demand function with respect to prices and quasifixed

[b]One of the reasons for this choice is the lack of data on some of the variables that are needed to estimate other flexible functional forms, such as translog or generalized symmetric McFadden.

[c]Both time and state indexes are dropped to avoid notational clutter.

inputs. Note that the input demand function is linear in parameters, which makes estimation easy.

The own-price and cross-price elasticity of the demand function (A.3) can be expressed, respectively, as

$$E_{ss} = \frac{\partial \ln x_s}{\partial \ln w_s} = \frac{w_s}{w_s}\frac{\partial x_s}{\partial w_s} \tag{A.4}$$

$$= \frac{Y}{2x}\left[\begin{array}{l}\alpha_{se}\left(\frac{w_e}{w_s}\right)^{0.5} + \alpha_{sm}\left(\frac{w_m}{w_s}\right)^{0.5} + \alpha_{sm}\left(\frac{w_m}{w_s}\right)^{0.5} \\ +\alpha_{sm}\left(\frac{w_m}{w_s}\right)^{0.5}\end{array}\right]$$

and

$$E_{sj} = \frac{\partial \ln x_s}{\partial \ln w_j} = \frac{w_j}{x_s}\frac{\partial x_s}{\partial w_j} = \frac{y}{2x_s}\left[\alpha_{sj}\left(\frac{w_j}{w_s}\right)^{0.5}\right], \tag{A.5}$$

where the subscripts i and j represent the ith and jth variable inputs. The own-price input demand function E_{11} must be negative, satisfying the law of demand. The cross-price elasticity can take any sign (not all of them being negative at the same time). A positive (negative) E_{sj} indicates that input s and j are substitutes (complementary) for each other.

The effect of changes in quasifixed factors on demand for a variable input can be captured by the elasticity of intensity.[7,9] Under our specification this can be expressed as

$$E_{xH} = \frac{H}{x_s}\frac{\partial x_s}{\partial H} = \frac{Y^{0.5}}{2x_s}\left(\beta_H H^{0.5} + \gamma_{tH} t^{0.5} H^{0.5}\right) + \frac{\gamma_H H}{x_s}. \tag{A.6}$$

A positive (negative) E_{xH} indicates that an increase in quasifixed factor increases (decreases) the demand for the ith variable input.

The effect of disembodied technological change is captured by the trend variable t. The proportionate change in demand for an input over time captures the effect of technological change on demand for that input. Under our specification this is

$$E_{xt} = \frac{\partial x_s}{\partial t}\frac{1}{x_s} = \frac{1}{2x_s}\left(\beta_{it} Y t^{-0.5} + 2\gamma_{it} Y + \gamma_{tH} Y^{0.5} H^{0.5} t^{-0.5}\right). \tag{A.7}$$

A positive (negative) E_{xt} indicates that technological change is input using (saving) due to a change in time, holding all other factors unchanged.

Estimation Procedure and Data

In this study we are mainly interested in examining the responsiveness of alfalfa seed demand for changes in prices and quasifixed inputs. Given data and the parameter estimates, one can calculate the elasticities mentioned above [(A.4)–(A.7)]. One of the following three econometric techniques can be used for this purpose: estimate the entire system of equations, consisting of the n number of input demand functions (A.3) and the cost function (A.2); estimate a system of equations consisting of only the input demand functions (A.3) (because n input demand equations exhaust all parameters of the cost function); or estimate only the alfalfa input demand function. The first two methods are no doubt better compared to the last one because they not only allow for cross-equation parameter restrictions but also accommodate cross-equation error correlation. However, the simultaneous equation estimation requires data on all inputs and their prices, which are not available. In fact, we could not obtain data on input quantities used in alfalfa production either at the national level or at the state level. So, in spite of its superior econometric estimation properties, use of a simultaneous equation estimation methodology seems inapplicable in the present context. Therefore, we used the third alternative, estimating only the alfalfa seed demand function. The estimated equation is

$$x_s = \mu_f + Y\left[\begin{array}{l}\alpha_{ss} + \alpha_{se}\left(\frac{w_e}{w_s}\right)^{0.5} + \alpha_{sm}\left(\frac{w_m}{w_s}\right)^{0.5} \\ +\alpha_{sl}\left(\frac{w_l}{w_s}\right)^{0.5} + \beta_{it}t^{0.5} + \gamma_{it}t\end{array}\right] + Y^{0.5}\left[\beta_{ih}H^{0.5} + \gamma_{ith}t^{0.5}H^{0.5}\right] + \gamma_{ih}H + e \tag{A.8}$$

where x_s is the demand for alfalfa seed and ε is the random error term. Subscripts e, m, and l represent the three variable inputs of energy, machinery, and labor, respectively; and μ_f are dummy variables for each state in the study.

Because the data set includes annual data of seven states, systematic variations due to state-specific factors is possible. State-specific fixed effect dummies μ_f are included to control for the state-specific effects. Individual t statistic of each state dummy or an F test that all state dummies are not different from zero simultaneously can be used to check the significance of the state dummies. To avoid a possible heteroskedasticity problem, following Parks,[8] both sides of Eq. (A.8) are divided by Y. The new error term $(\varepsilon_{ft}/Y_{ft})$ is likely to have homoskedastic variance. A Lagrange multiplier test[5,6] was used to test for autocorrelation. Use of this method involves estimation of the autocorrelation coefficient ρ and then the use of the t test to check if the estimated ρ is significantly different from zero. The autocorrelation coefficient ρ is calculated as

$$\rho = \frac{\sum_i \sum_t \varepsilon_{i,t}\varepsilon_{i,t-1}}{\sum_i \sum_t \varepsilon_{i,t-1}^2},$$

The estimated value of ρ is 0.6879 and the estimated LM test statistic is 11.93. The critical t value at the 5% level of significance is 1.69, indicating the existence of serial autocorrelation. To correct for autocorrelation, the Prais–Winsten transformation method was applied.[12]

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