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An acreage response model for Arkansas rice farms

J. Grant Ballard and Michael R. Thomsen†*

ABSTRACT

In recent years, market forces have signaled a strong demand for rice as well as other Arkansas crops. However, high fuel, fertilizer, and chemical costs have negatively impacted farm income, and these input costs are widely known to impact planting decisions of farmers. The goal of this study is to develop and estimate an acreage response model for rice. The model is used to compute acreage response elasticities and provides insight into roles that input costs and crop prices play in acreage decisions made by producers. Economic theory predicts that prices for important inputs such as fuels and fertilizers as well as the relative prices of rice and soybeans will impact acreage decisions. Soybean prices are expected to be important because most of the machinery needed to produce rice and soybeans is the same and these crops are already used commonly in rotation. Results of the study show that crop price variables do indeed play a significant role in producer planning. Short- and long-run own-price acreage response elasticities are estimated to be 0.69 and 1.19, respectively. Soybean prices have the expected negative impact on rice acreage with a cross-price elasticity of -0.33 in the short run and -0.57 in the long run. On the other hand, the expected economic impacts of input prices on rice acreage were not supported by the results. Estimated relationships were negative, as would be predicted by economic theory, but were not statistically significant.

* J. Grant Ballard completed his BSA in agricultural business in December 2007 and is entering the University of Arkansas School of Law in August 2008. This paper is based on his honors research project that he completed while a senior in the Dale Bumpers College studying in the Department of Agricultural Economics and Agribusiness.

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MEET THE STUDENT-AUTHOR

J. Grant Ballard

I am a native of Roland, Ark., and a 2004 graduate of Little Rock Central High School. Upon graduation from high school, I enrolled at the University of Arkansas in the Department of Agricultural Economics and Agribusiness. I completed my B.S. degree in December 2007 with a major in agribusiness and a minor in environmental, soil, and water science. While an undergraduate at the University of Arkansas, I was a member of the Alpha Gamma Rho Fraternity, Agribusiness Club, Collegiate Farm Bureau, Order of Omega, and Alpha Zeta. I also had the honor of serving the Bumpers College as a student ambassador. I was Vice Noble Ruler of Alpha Gamma Rho in 2006, and I was president of the University of Arkansas chapter of Collegiate Farm Bureau in 2007. I will begin law school in fall 2008 at the University of Arkansas at Fayetteville.

This field of research was selected because of my personal interest in agricultural economics and rice production as well as the economic importance of rice production and milling to the study region and the state. I would like to thank Dr. Michael Thomsen for his guidance, time, and commitment to this study.

INTRODUCTION

In recent years, market forces have signaled a strong demand for rice and other Arkansas crops. This demand fueled a growth in Arkansas crop sales. However, high fuel, fertilizer, and chemical costs have negatively impacted farm income (Childs and Livezey, 2006), and these input costs are widely known to impact planting decisions of farmers. In eastern Arkansas, rice and soybeans are commonly grown in rotation in order to control weed populations in rice fields. Most eastern Arkansas soils that are suited for rice are also well suited for soybean production, and that makes this arrangement economically sound. Growers clearly have the option to grow rice, soybeans, or other possible crops. Aside from agronomic considerations, producers will base their planting decisions on expected profitability (Kay, Edwards, and Duffy, 2004). For a variety of reasons, a producer could decide to dedicate more of his/her acreage to soybeans or other crops and less to rice. Rice is more capital intensive than soybeans (Childs and Livezey, 2006), and in years with higher input costs or lower average rice prices, it would be expected that a lower than average acreage would be planted in rice.

The objective of this study is to develop and estimate an acreage response model for rice. The model will be used to compute acreage response elasticities and will provide insight on the role that input costs and crop prices play in acreage decisions made by producers in the selected study region. It is expected that prices for important inputs such as fuels and fertilizers as well as relative prices of rice and soybeans will impact acreage decisions. Soybean prices are expected to be important because most machinery needed to produce rice and soybeans is the same and these two crops are already used commonly in rotation.

MATERIALS AND METHODS

Acreage Response Model

Shumway (1986) summarizes supply relationships for several southern US crops and provides an overview of empirical methods of supply estimation. Economic theory indicates that supply depends on the price the producer expects to receive at harvest along with the prices of inputs and the expected profitability of other competing crops (Hudson, 2007). Several approaches are available for specifying an expected price. Nerlove (1958) championed the use of the adaptive expectations model for the analysis of agricultural supply functions. This is a very common approach and many textbooks on the subject of econometrics discuss this model and present issues involved in its estimation (Maddala, 1992; Kmenta, 1986). The adaptive expectations model provides one way to address price expectations even though such expectations are not observed. Producers cannot always accurately predict price they will receive but it is reasonable to assume that producers' expectations of price are expressed as a weighted average of past prices (Nerlove, 1958). The weights of past prices are functions of λ, where λ is a coefficient between zero and one. Specifically, expected prices are expressed as:

(1)

$$P^*_{t+1} = (1-\lambda)P_t + (1-\lambda)\lambda P_{t-1} + (1-\lambda)\lambda^2 P_{t-2} + (1-\lambda)\lambda^3 P_{t-3} + \ldots\ldots$$

According to equation (1) the expected price in any given period depends on prices that have been observed in the past. The influence of observed prices on this expectation will decline as one goes back in time, since λ is between zero and one. The goal is to represent expected price in some manner that does not require an infinite number of observations on past prices. This can be accomplished by lagging equation 1 by one period and multiplying through by λ to get:

(2)

$$\lambda P^*_t = (1-\lambda)\lambda P_{t-1} + (1-\lambda)\lambda^2 P_{t-2} + (1-\lambda)\lambda^3 P_{t-3} + \ldots\ldots\ldots$$

Subtracting equation (2) from equation (1) provides:

(3)

$$P^*_{t+1} - \lambda P^*_t = (1-\lambda)P_t$$

The usefulness of equation (3) will be clear momentarily.

A linear econometric model for the acreage response function for rice is given by:

(4)

$$Q_t = \alpha + \beta P^*_t + \sum_{i=1}^{N} \gamma_i Z_{it} + U_t$$

Where Q_t is acreage, P_t^* is expected rice price, and the Z_{it} are exogenous variables reflecting the profitability of soybeans (a competing crop) and prices of inputs. Lagging equation 4 by one period and multiplying through by the partial adjustment coefficient, λ, provides:

(5)

$$\lambda Q_{t-i} = \lambda\alpha + \lambda\beta P^*_{t-1} + \lambda\sum_{i=1}^{N} \gamma_i Z_{it-1} + \lambda U_{t-1}$$

Subtracting equation 5 from equation 4 provides:

(6)

$$Q_t = (1-\lambda)\alpha + \lambda Q_{t-1} + \beta(P^*_t - \lambda P^*_{t-1}) + \sum_{i=1}^{N} \gamma_i (Z_{it} - \lambda Z_{it-1}) + U_t - \lambda U_{t-1}$$

which, by equation 3, can be expressed in terms of observed variables as:

(7)

$$Q_t = (1-\lambda)\alpha + \lambda Q_{t-1} + \beta(1-\lambda)P_{t-1} + \sum_{i=1}^{N} \gamma_i (Z_{it} - \lambda Z_{it-1}) + U_t - \lambda U_{t-1}$$

Equation 7 is a function of observed variables and can be used to uncover estimates of the parameters from the theoretical model in equation 4. There is one problem that complicates the estimation of equation 7 in that the error term is correlated with Q_{t-1}, one of the regressors. As a result, the method of ordinary least squares will provide inconsistent parameter estimates. For this reason, Maddala (1992) discusses the use of non-linear least squares to estimate equation 7.

Computation of Elasticities

The parameter estimates observed from equation 7 make it possible to calculate point estimates for acreage response elasticities. The estimated own-price coefficient (β) and estimates for coefficients on exogenous variables (γ_i) are used to determine point estimates for acreage response elasticities. Specifically, the own-price elasticity of supply is given as:

(8)

$$\beta \frac{P}{Q}$$

and the elasticity of supply with respect to the ith exogenous variable is given by:

(9)

$$\gamma_i \frac{Z_i}{Q}$$

Long-run acreage response elasticities can be computed by dividing the short-run elasticity computed from either equation 8 or 9 by ($1-\lambda$) (Nerlove and Addison, 1958).

Data

Data for this study were collected from the United States Department of Agriculture National Agricultural Statistics Service (NASS, 2007) and the United States Department of Labor Bureau of Labor Statistics (BLS) (2007a; 2007b). NASS provided average yearly prices for rice and soybeans as well as county-level information on acres planted, acres harvested, and average yield. Producer Price indexes (PPI's) for petroleum products and for fertilizer products were collected from BLS (2007a) in order to demonstrate changes in prices paid by producers for inputs. The producer price index measures average change over time in selling prices received by domestic producers for their output. The BLS's (2007b) Consumer Price Index (CPI), which measures general inflation in the US economy, was used to adjust all prices and PPI measures for inflation.

The study region consists of 55 counties and parishes in the states of Arkansas, Mississippi, Missouri, and Louisiana. The selected counties and parishes are all found in what NASS classifies as the Mississippi Delta region and in the East Arkansas Non-Delta region (Livezey and Foreman, 2004). Production practices throughout the region are similar, and costs of production as well as returns should be fairly standard across the region. In order to accurately assess impacts of input costs and crop prices upon acreage decisions of farmers, only those counties with a regular history of rice production were included. The criterion used to include or exclude counties from the study region was for the county to have reported rice production in each of the past 10 years. A graphic of the study region used for this study is presented in Figure 1.

Rice acreage, the dependent variable for the acreage response model, was obtained by summing acres harvested over all counties and parishes in the study region for each year. Based on 2000 to 2006 production data from NASS, the 55 counties and parishes in the study region accounted for 62% of all US rice production and approximately 80% of US long grain rice production. Soybean price was considered exogenous for the purposes of this study. In terms of national production, the study region was responsible for a small portion (approximately six percent) of the total US soybean production. The implicit assumption here was that producers in the study region can sell all the soybeans they want at prevailing prices.

In developing the dataset it was important to account for the impact of policy on producer behavior. Beckman (2005) provides a good summary of US farm policy that affects rice production. Supply controls such as acreage adjustments, marketing quotas, price supports, and storage of excessive supplies under loan were a part of the government policy toward basic US commodities for much of the twentieth century. The rice acreage allotment system was eliminated with the Farm Bill of 1981. The Marketing Loan Program allows producers to obtain a loan from the Commodity Credit Corporation (CCC). The producer uses his current year production as collateral. The loan rate creates a price floor, and producers are eligible for a marketing loan gain (MLG) when world price falls below the loan rate. Loan Deficiency Payments (LDPs) are also available to producers under the Marketing Loan Program. Again, these payments are available when world price falls below the loan rate. Producers can take this direct payment instead of securing a Marketing Assistance loan. Because the loan rate acts as a price floor that maintains a certain level of production, the price of rice was modified to reflect the larger of (a) the loan rate or (b) the price reported by NASS (2007). Loan rate data were gathered from the USDA's Economic Research Service.

The period chosen for this study reflects 30 years beginning with 1977 and extending through 2006. Although the earliest years in the dataset reflect conditions under the acreage allotment system, which limited producer responses to price signals, the goal here is to obtain a dataset that reasonably reflected recent production practices but still contained enough observations for the statistical methods to be reasonably powerful. Descriptive statistics for variables used in the acreage response model are reported in Table 1.

RESULTS AND DISCUSSION

Table 2 presents results of the estimated acreage-response model. The estimate column displays the parameter estimates of the model. These estimates demonstrate the impact of an increase in rice price, soybean price, fuel price, and fertilizer price. These estimated impacts can be used to determine how producers respond to changes in these variables. For example, if rice price were to increase by $1 per cwt., then according to the results rice acres harvested would increase by 173,643 acres. If soybean price was to increase by $1 a bushel, then rice acreage would drop by 108,915 acres. Continuing with this analysis, if fuel price and fertilizer price were to increase by the same amount per unit, acreage would shift down 125 acres and down 5,107 acres, respectively. However, one must also consider the magnitude of the t-values reported in Table 2. The t-values for fuel and fertilizer prices are small in magnitude and indicate a lack of statistical evidence for these variables having an effect on acreage decisions.

The conclusion to be drawn from Table 2 is that rice and soybean prices have the most significant impact upon acreage devoted to rice while fuel and fertilizer prices seem insignificant. The insignificant impacts of fuel and fertilizer prices are perplexing because economic theory would suggest acreage should be reduced as input prices increase. To explore the issue further the model was re-estimated without the fertilizer price because fuel and fertilizer prices are highly correlated. This alternative specification did not meaningfully change the results. After fertilizer was dropped, the fuel coefficient was still positive and insignificant.

Acreage response elasticities (Table 3) are computed at the sample means. Again, it is important to keep in mind that the coefficients on fuel and fertilizer price variables were insignificant and so the fuel and fertilizer elasticities are suspect. The short-run own-price elasticity is 0.69 and can be interpreted as indicating that all else equal, a one percent increase in the price of rice will result in 0.69 percent increase in acreage devoted to rice production. The long-run own-price elasticity of 1.19 is larger in magnitude and is consistent with the idea that production decisions are more flexible over a longer planning horizon. Other elasticity estimates reported in Table 3 can be interpreted in the same fashion.

Discussion

The objective of this study was to determine acreage response of rice to changes in crop price and increasing costs of inputs. The goal was to identify the impact of these factors upon planting decisions of rice producers in the study region. Economic theory predicts that expected returns motivate planting decisions, and results presented here provide clear evidence that crop price variables play an important role in producer planning. All else equal, when price of a crop increases, supply will follow. Similarly, the model showed that as soybean prices increase, acreage shifts out of rice. This is again a basic economic principle that makes good sense for business application.

The expected economic impacts of input prices, on the other hand, were not supported by the results. Rice acreage was not found to be significantly responsive to fuel costs or fertilizer costs. This may suggest that input costs are not as significant as expected price when producers make their planting decisions. However, it is more likely that the lack of significance is a feature of the problem being analyzed. Specifically, inputs such as fuel make up about the same percentage of total cost for production with irrigated soybeans as with rice. Fuel costs average approximately 15 to 20 percent of cost for production with both crops (Watkins, 2006). Producers will spend less to make a crop of soybeans because the crop is not as input-intensive, but the returns will generally be higher for rice if the price is competitive due to rice being a higher yielding crop than soybeans.

Agriculture is changing rapidly in the present day. The 2006 crop year was the last year analyzed in this study. Since then, many new issues have arisen that could bring attention to the questions addressed in this study. Basis has reached record highs in many regions and the ethanol boom has shifted much acreage into corn and out of soybeans in the past year. In future research, a market equilibrium model could be useful for a study of the Midwest corn and soybean crops. In the Midwest, where corn and soybean prices would not be considered exogenous, it may be easier to estimate the impact that fuel prices have on equilibrium prices of these crops and then to examine how the impact of those price changes indirectly impact rice prices and consequently rice acreage.

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Table 1. Descriptive statistics for the study region 1977-2006.[A]

Variable	Description	N	Mean	Std Dev	Minimum	Maximum
Rharv	Rice Acres Harvested	30	1,694,145	316,640	985,490	2,227,400
Rprice	Rice Price ($/cwt.)	30	6.88	3.46	3.61	15.66
Sprice	Soybean Price ($/bu.)	30	4.99	2.18	2.47	10.21
Fert	Fertilizer Price (PPI)	30	81.05	15.41	57.70	111.33
Petro	Petroleum Price (PPI)	30	61.92	23.33	31.47	116.50

A. All prices and price indexes are adjusted for inflation and are in constant 1982-1984 dollars.

Table 2: Parameter estimates for the acreage response model

Parameter	Variable	Estimate	Std Err	t Value
λ	Partial adjustment coefficient	0.42	0.16	2.66
α	Intercept	2,843,321	645,278	4.41
β	Rice price ($/cwt.)	173,643	71,069	2.44
γ_1	Soybean price ($/bu.)	-108,915	38,729	-2.81
γ_2	Fuel price (PPI)	-126	2,499	-0.05
γ_3	Fertilizer price (PPI)	-5,107	6,703	-0.76

Table 3: Elasticities of rice acreage

Variable	Short-run elasticity	Long-run elasticity
Rice price	0.69	1.19
Soybean price	-0.33	-0.57
Fuel price	-0.006	-0.01
Fertilizer price	-0.19	-0.33

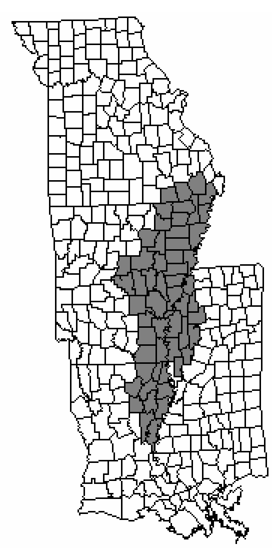

Fig. 1. Counties and parishes included in the Study Region