AN ANALYSIS AS TO THE CAUSAL RELATIONSHIP BETWEEN BIOETHANOL EXPANSION AND AGRICULTURAL CROP ACREAGE ALLOCATION IN THE UNITED STATES

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Abstract

This study analyzes the historical price response of individual crop acreage in order to determine the impacts of an expansionist policy in bioethanol production on the U.S. agricultural industry. In doing this, this study provides an economic foundation by using a traditional Rotterdam model to simulate a cropland demand system. Within the developed framework, this study estimates own and cross acreage elasticities and scale elasticities to show the impacts of acreage values on crop production and the relationship between total cropland and individual crop acreage. This study found that rice farming is most inelastic to own acreage value. Soybeans, hay, and wheat are shown to be good substitute crops for corn. Corn, soybeans, hay, wheat, cotton, barley, and rice are shown to have positive scale elasticity, while sorghum and oats are shown to have negative scale elasticities. The scale effects of corn, soybeans, hay, and wheat are relatively large, while those of cotton, sorghum, barley, rice, and oats are relatively small.

Key words: bioethanol, acreage value, Rotterdam model, own acreage elasticity, cross acreage elasticity, and scale elasticity

Related to current expectations regarding the role of bio-fuels in the energy market, there has been a recent call on the agricultural industry to transform its traditional role in which it produces food, feed, and fiber into a role with a greater focus on the production of energy (Lynn et al., 2007 and Daniel et al., 2007). Bioethanol, principally derived from corn, is the dominant biofuel used in the United States (Masami, 2007). Increased demand for corn, now not only for traditional food and feedstock purposes but also as a principle source of biomass for the production of bioethanol, is contributing to the steep increase in corn prices which, in turn, is prompting farmers to allocate more of their available cropland for corn production. (Simla et al, 2007). Simultaneously, it is unlikely that additional cropland will be added in the United States to accommodate increases in corn demand (Energy Information Administration, 2007). Instead, cultivated crops will compete with each other for crop acreage allocation, resulting in an inter-crop competition for available land (Daniel et al., 2003). Therefore, cropland allocation will be adjusted depending upon the current economic values of the various crops. In this process, expanded production in some crops will imply that the cropland area dedicated to other crops will be reduced given limited cropland availability. This inter-crop competition for crop acreage will increase prices for other agricultural crops such as soybeans, wheat, rice, and even hay and cotton because these crops are necessary for the maintenance of current food, feed, and fiber consumption levels. In order to accomplish this, certain food, feed, and fiber production targets must be maintained to ensure uninterrupted supply. Furthermore, demand for these crops is also increasing with annual increases in population and growth in the food industry (USDA, 2007). However, any decrease in the acreage of these crops will reduce the production of these crops, which in turn will increase the prices of these crops. For example, corn acreage has increased from 79,551 thousand acres in 2000 to 93,600 thousand acres in 2007 as a result of an increase in the price of corn from $1.85/bu in 2000 to $4.00/bu in 2007. However, production acreage has decreased by 10,635 thousand acres for soybeans, 2,116 thousand acres for wheat, 299 thousand acres for rice, 1,891 thousand acres for hay, and 4,687 thousand acres for cotton, respectively. At the same time, the price has increased from $4.54/bu to $10.40/bu for soybeans, from $2.62/bu to $6.65/bu for wheat, from $5.61/cwt to $11.50/cwt for rice, from $96.50/ton to $133.00/ton for hay, and from $0.516/lb to $0.569/ob for cotton, respectively, during this same period of time.

Furthermore, agricultural production is more heavily dependent on natural conditions such as temperature, disease, and drought conditions as compared to the manufacturing and service industries. Production risks stemming from unfavorable natural (environmental) conditions are a cause for concern as they result in increased price instability in commodity markets. All of these unstable (relatively speaking) agricultural market circumstances tie in closely to overall agricultural industry effectiveness not only in supplying the traditional food, feed, and fiber industries but also as to its ability to simultaneously fulfill its new role as a primary biomass supplier to the nation's biofuel energy market.

In light of this new demand for agricultural products, this study is examines historical crop acreage adjustments as they have responded to changes in price for agricultural products. This study will estimate the price elasticity of acreage which can be used as a guide in foreseeing crop acreage allocation as they respond to changes in market prices. Even though many previous studies have estimated and reported acreage elasticities in an effort to estimate agricultural supply response to price fluctuations (Carlos and David, 2007; Chambers and Just, 1989; Shumway, et al., 1988; Morzuch, et al., 1980; Meilke and Kramar, 1976), all of the efforts of the studies have focused on supply elasticities because farmers are recognized only as crop producers. However, this study observes the farmer as a land consumer trying to maximize utility in using available cropland so that acreage elasticity can be estimated in a traditional demand system. A farmer's utility depends upon the value produced by the land, which is directly linked to farm profit.

In order to achieve the objective, this study is conducted as follow: in the next section a theoretical foundation for the system of acreage share equations will be discussed. In this discussion, the terms '*utility*' for a land consumer and '*acreage value*' for price will be employed because this study recognizes farmers as land consumers. The second will discuss data and model estimation. The next section will discuss results obtained from the model, followed by a study summary and conclusions in the final section.

THEORETICAL APPROACH

Farmers decide what kind of crops to produce on their cropland. In this decision making process, the farmer tries to maximize profit. Given cost, farmers' profit will depend on prices and yields of crops produced on their land. By using price and yield data, a crop's acreage value will be defined as follows:

(1) $v_i = p_i y_i$,

where p_i and y_i are price and yield for crop *i*.

The acreage value of a crop will be a key factor in the crop allocation decision making process for a profit maximizing firm. Whatever crops are chosen, profit will be summarized as follows:

(2) $\pi = \sum_i v_i a_i - C$,

where a_i is the number of acres for crop *i*, and *C* is cost. Since total available land is fixed, the sum of acreage is represented as follows:

(3) $\sum_i a_i = L$.

The total value produced on *L* given p_i is as follows:

(4) $\sum_i v_i a_i = M$.

Just as other consumers demand certain commodities, farmers can be recognized as cropland consumers, whereby they satisfy their utility preference not only for economic benefit but for non-economic benefit as well, such as land conservation and cultural heritage purposes. For example, as a land consumer, the utility of consuming land will depend upon the acreage value of each area of land, taking into account both economic and non-economic values. Therefore, acreage value represents the marginal utility of consuming one unit land. Given a fixed amount of land, this relationship is defined as follows:

(5) $u = U(a_1, \ldots, a_n)$ s.t. $\sum_i v_i a_i = M$.

Now, the farmer's decision making process in selecting a crop for production on their share of cropland can be described in the framework of a utility maximizing process, assuming that cost is held constant.

Because the number, *n*, of different cropland acreage shares that farmers use are relatively small compared to the number of commodities that consumers buy, empirical cropland demand analysis can be better carried out than general demand analysis in which the number of different commodities are vast.[1] In particular, since all different cropland acreage can be included into the direct utility function and value equation as defined in equation (5), no separability or aggregation assumptions are needed to derive a system of land demand equations.[2] Through using duality, developed extensively in consumer theory, the land consumer's indirect utility function can be obtained from equation (5) as follows:

(6) $\tilde{u} = \tilde{U}(v_1, \ldots, v_n, M)$.

As shown, this indirect utility function is a function of acreage value, v_i, and total value, *M*. Here, we should note that a farmer's utility increases with an increase in cropland acreage value. As a result, the two different properties of a land consumer's indirect utility function from an ordinary indirect utility function are as follows: 1) $\tilde{U}(v, M)$ is increasing; and 2) $\widetilde{U}(v, M)$ is quasi-concave in v.[3] This condition can be summarized as follows:

(7) $$\frac{d\widetilde{u}}{dv_i} > 0 ,$$

(8) $$\frac{d^2\widetilde{u}}{dv_i dv_i} > 0 .$$

The second property of a land consumer’s indirect utility function dictates that own acreage elasticity in a land demand system should be positive. Since it is not the purpose of this study to demonstrate the duality of a land consumer’s utility function, we will not go into further discussion regarding the relationship between land consumer direct and indirect utility functions. Instead, this study will employ the Rotterdam model as developed in previous studies because use of the empirical Rotterdam model can show whether the non-negativity requirement of own acreage elasticity is satisfied or not.

Land consumer allocation systems determine how the land consumers allocate their lands over individual crops. This concept is similar to Barten’s concept of consumer allocation systems which indicate how the consumer allocates means over the purchase of various commodities. In particular, Barten emphasized that the functional form of consumer allocation models should be able to satisfy theoretical properties derived from the economic theory. His study sketched four approaches that meet this condition. The Rotterdam model is one of the four functional forms used as a consumer allocation model. For land consumer allocation systems in this study, the Rotterdam model will be used and defined as follows:

(7) $$w_i d \ln a_i = h_i d \ln Q + \sum_j h_{ij} d \ln v_j ,$$

where $w_i = v_i a_i$ is cropland value share, i, and $d \ln Q = \sum_i w_i d \ln v_i$ is the Divisia volume index. The solution to the Slutsky matrix of the land demand system yields the following acreage elasticity and scale elasticity:

$$\varepsilon_{ii} = \frac{h_{ii}}{w_i} - h_i \,, \tag{8}$$

$$\varepsilon_{ij} = \frac{h_{ij}}{w_i} - h_i \frac{w_j}{w_i} \,, \tag{9}$$

$$\eta_i = \frac{h_i}{w_i} \,, \tag{10}$$

where ε_{ii} is own acreage elasticity, ε_{ij} is cross acreage elasticity, and η_i is scale elasticity. The properties of a land consumer's indirect utility function defined in equation (8) force $\varepsilon_{ii} > 0$. Two cropland allocations, *i* and *j*, are complements if $\varepsilon_{ij} > 0$ and substitutes if $\varepsilon_{ij} < 0$.

Due to theoretical constructs that the Rotterdam model adheres to, the following constraints from economic theory must be directly applied to its parameters and are as follows:

(11) Adding up $\sum_i h_i = 1$ and $\sum_i h_{ij} = 0$,

(12) Homogeneity $\sum_j h_{ij} = 0$,

(13) Slutsky Symmetry $h_{ij} = h_{ji}$,

(14) Non-negativity $\sum_i \sum_j a_i h_{ij} a_i > 0$.

ESTIMATION

DATA

In order to construct the empirical Rotterdam model, this study used annual data for crop acreage, price, and yield from 1963 and 2007. The data, obtained from the National Agricultural Statistics Service (website: http://www.nass.usda.gov/QuickStats/PullData_US.jsp, access date: February 26, 2008), are total arable land and acres, prices, and yields for corn, soybeans, hay, wheat, cotton, sorghum, barley, rice, and oats. This study used harvested acreage values for each crop. To make the data consistent, , total arable land was weighted by the average ratio of planted acres to harvested acres for the nine crops (corn, soybeans, hay, wheat, cotton, sorghum, barley, rice, and oats). Other crop acreage was obtained by extracting the sum of acres for the nine crops from the harvested total acres. Since the harvested total acres include all crops to be produced, this empirical model needs no separability assumption in constructing the land demand model. This study used price and yield data of each crop in order to calculate the acreage value of each cropland share. In doing this, this study used the higher price between market prices and commodity program prices for corn, soybeans, wheat, cotton, sorghum, barley, rice and oats. The index of price received by farmers was used as the acreage value for the other aggregated crops.

EMPIRICAL MODEL

To estimate acreage elasticity parameters and scale elasticity parameters for the Rotterdam model (7), the specification must be modified to reflect the discrete-time nature of the data and is accomplished as follows:

$$\overline{w}_i \Delta \ln a_i = h_i \Delta \ln Q + \sum_j h_{ij} \Delta \ln v_j , \tag{15}$$

where $\overline{w}_{it} = (w_{it} + w_{it-1})/2$ is the two year moving average in the acreage share for crop *i* in total value of *L*. In the empirical model, this study used a moving average acreage share to avoid a simultaneity problem (Haden, 1990). Zellner's Seemingly Unrelated Regression (SUR) was used as an econometric methodology because individual crop acreages are contemporaneously competing with each other. This study further imposes the demand theory restrictions of both homogeneity (12) and symmetry (13). This study will confirm whether or not the adding-up and non-negativity conditions are satisfied in the empirical Rotterdam model.

RESULTS

Table 1 shows the summary statistics related to acreage and acreage value for individuals crop from 1963 to 2007. On average, during this period of time, corn acreage was the largest among crop acreage allocations. Corn acreage represents 16% of total crop acreage. Hay acreage is 15% of total crop acreage. Soybean and wheat acreage are 14% of total crop acreage, respectively. Cotton and sorghum acreage are around 3% of total crop acreage, respectively. Barley and oat acreage are around 2% of total crop acreage. Rice acreage is around 1% of total crop acreage. The sum for other crop acreage is around 30% of total crop acreage. The acreage value of soybeans is largest among the nine crops' acreage values, representing $90.17 per acre. The acreage value of oats is $88.55 per acre, second in rank, behind that of soybeans. The acreage value of sorghum is $87.14 per acre, keeping it in third place. The acreage value of corn is $81.02 per acre. The acreage value of hay is $84.59 per acre. The acreage value of wheat is $84.34 per acre. The acreage value of cotton is $75.76 per acre, taking the last place in the rank. The acreage value of barley is $84.51 per acre. The acreage value of rice is $81.51 per acre.

As Table 1 shows, the acreage of individual crops is not proportional to their acreage value. For example, corn acreage is the largest among the nine crop acreage allocations but the acreage value of corn is the second lowest among the nine acreage values. This implies conditions of natural restrictions, asset fixity, and non economic value for farming.

Table 2 shows acreage and scale elasticity coefficients. As this study discussed, the condition of non-negativity was satisfied. That is, all diagonal elements of elasticity coefficients matrix are greater than zero. However, the adding up condition was not satisfied. The scale coefficients for sorghum and oats are negative in sign, representing the acreages for sorghum and oats have decreased with an increase in total acreage. The coefficients for the study’s other crops are positive in sign and exhibit non-homethetic preferences. Fifty-two (52) coefficients of the total 65 coefficients estimated in the model are shown to be significant at the 5% level.

Table 3 shows own and cross acreage elasticities and scale elasticities. The own acreage elasticities for individual crops are calculated using equation (8). The own acreage elasticities are shown to be positive. In addition, the own acreage elasticities are shown to be inelastic, implying that a change in crop acreage is less sensitive than a change in acreage value (or a change in price under given yield). In particular, a smaller own acreage elasticity represents the level of increased difficulty in changing acreage to respond to a change in acreage value. If the own acreage elasticity of rice is smaller than that of barley, a greater percentage increase in the acreage value of rice is needed as compared to the acreage value of barley in order to increase its respective land usage by one percent. For example, the own acreage elasticity of rice is 0.3567 and the own acreage elasticity of barley is 0.9963. These two elasticities show that in order to increase rice acreage by one percent, a 2.8032% increase in the acreage value of rice must occur. However, a 1% increase in the acreage value of barley is enough to increase barley acreage by one percent. The own acreage elasticity of corn is 0.7751, implying that in order to increase corn acreage by one percent, the acreage value of corn must be increased by 1.2902%. The own acreage elasticity of soybean is 0.7233, implying in order to increase soybean acreage by one percent, the acreage value of soybean must be increased by 1.3825%. The own acreage elasticity of hay is 0.8221, implying that in order to increase hay acreage by one percent, the acreage value of hay must be increased by 1.2164%. The own acreage elasticity of wheat is 0.7753, implying that in order to increase wheat acreage by one percent, the acreage value of wheat must be increased by 1.2899%. The own acreage elasticity of cotton is 0.8925, implying that in order to increase cotton acreage by one percent, the acreage value of cotton must be increased by 1.1205%. The own acreage elasticity of sorghum is 0.8210, implying that in order to increase sorghum acreage by one percent, the acreage value of sorghum must be increased by 1.2180%. The own acreage elasticity of oats is 0.6710, implying that in order to increase oat acreage by one percent, the acreage value of corn must be increased by 1.4904%.

Except for cross acreage elasticities of rice for barley, oats for barley, and oats for rice, which are statistically insignificant at the 10% level, all cross acreage elasticities are shown to be negative, implying that cropland are substitutes for each other. For corn, soybeans, hay, wheat, cotton, barley, and rice, other crop is shown to be most substitutable crop. For sorghum, wheat is shown to be the best substitute. For oats, soybeans are shown to be the ideal substitute. As this study expected, the magnitude of cross acreage elasticity is smaller than that of own acreage elasticity. A 1% increase in acreage value of corn decreases crop acreage by 0.1956% for soybeans, by 0.2111% for hay, by 0.2095% for wheat, by 0.1546% for cotton, by 0.1188% for sorghum, by 0.2138% for barley, by 0.0927% for rice, and 0.1632% for oat. The acreage value of corn the most largely affects on barley acreage and the least affects on rice acreage.

A 1% increase in acreage value of soybean decreases crop acreage by 0.2022% for corn, by 0.1937% for hay, by 0.1598% for wheat, by 0.1501% for cotton, by 0.0188% for sorghum, by 0.1721% for barley, by 0.1048% for rice, and 0.2386% for oat. The acreage value of soybeans affects oats acreage the most and sorghum acreage the least. A 1% increase in the acreage value of hay decreases corn acreage by 0.1995%, soybean acreage by 0.1769%, wheat acreage by 0.2187%, cotton acreage by 0.1366%, sorghum acreage by 0.1665%, barley acreage by 0.1581%, rice acreage by 0.0479%, and oat acreage by 0.0514%. The acreage value of hay affects wheat acreage the most and rice acreage the least. A 1% increase in the acreage value of wheat decreases crop acreage by 0.1991% for corn, 0.1452% for soybeans, 0.2199% for hay, 0.0751% for cotton, 0.2188% for sorghum, 0.3150% for barley, 0.0783% for rice, and 0.0461% for oats. The acreage value of wheat affects barley acreage the most and oats acreage the least. A 1% increase in the acreage value of cotton decreases crop acreage by 0.0281% for corn, 0.0260% for soybeans, 0.0262% for hay, 0.0152% for wheat, 0.0477% for sorghum, 0.0407% for barley, 0.0128% for rice, and 0.0426% for oats. The acreage value of cotton affects sorghum acreage the most and rice acreage the least. The cross effect of cotton acreage value is relatively small, compared to the cross effect of other major crops such as corn, soybeans, and wheat on acreages. A 1% increase in acreage value of sorghum decreases crop acreage by 0.0339% for corn, 0.0127% for soybeans, 0.0447% for hay, 0.0551% for wheat, 0.0628% for cotton, 0.0536% for barley, 0.0167% for rice, and 0.0452% for oats. The acreage value of sorghum affects cotton acreage the most and soybean acreage the least. A 1% increase in acreage value of barley decreases crop acreage by 0.0266% for corn, 0.0207% for soybeans, 0.0210% for hay, 0.0409% for wheat, 0.0285% for cotton, 0.0277% for sorghum, 0.0332% for rice, and 0.0236% for oats. The acreage value of barley has the greatest impact on wheat acreage and affects soybean acreage the least. A 1% increase in acreage value of rice decreases crop acreage by 0.0168% for corn, 0.0173% for soybeans, 0.0104% for hay, 0.0151% for wheat, 0.0126% for cotton, 0.0074% for sorghum, 0.0382% for barley, and 0.0051% for oats. The acreage value of rice affects barley acreage the greatest and oats acreage the least. A 1% increase in acreage value of oats decreases crop acreage by 0.0322% for corn, 0.0424% for soybeans, 0.0160% for hay, 0.0151% for wheat, 0.0435% for cotton, 0.0344% for sorghum, 0.0215% for barley, and 0.0001% for rice. The acreage value of oats affects cotton acreage the most and rice acreage the least. Corn, soybeans, hay and wheat have relatively large cross effects with those of cotton, sorghum, barley, rice, and oats being relatively small.

As this study discussed in the previous section, the notion of scale elasticity represents the relationship between individual crop acreage and total crop acreage. If the sign of the scale elasticity is positive, individual crop acreage increases with an increase in total crop acreage. For example, if the scale elasticity of corn is positive, then the corn acreage increases with an increase in total crop acreage. If the sign of the scale elasticity is negative, individual crop acreage decreases with an increase in total crop acreage. For example, the scale elasticity of sorghum is negative, then sorghum acreage decreases with an increase in total crop acreage. In this study, corn, soybeans, hay, wheat, cotton, barley, and rice are shown to have positive scale elasticities, while sorghum and oats are shown to have negative scale elasticities. This indicates that sorghum and oats are viewed by producers as inferior, relative to the other crops.

The scale effects of corn, soybeans, hay, and wheat are relatively large and the scale effects of cotton, sorghum, barley, rice, and oats are relatively small. The scale elasticity of corn is 0.3665, implying corn acreage increases by 0.3665% when total crop acreage increases by 1%. The scale elasticity of soybeans is 0.2855, implying soybean acreage increases by 0.2855% when total crop acreage increases by 1%. The scale elasticity of hay is 0.3263, implying hay acreage increases by 0.3263% when total crop acreage increases by 1%. The scale elasticity of wheat is 0.3324, implying wheat acreage increases by 0.3324% when total crop acreage increases by 1%. The scale elasticity of cotton is 0.0483, implying cotton acreage increases by 0.0483% when total crop acreage increases by 1%. The scale elasticity of sorghum is -0.0035, implying sorghum acreage decreases by 0.0035% when total crop acreage increases by 1%. The scale elasticity of barley is 0.0384, implying barley acreage increases by 0.0384% when total crop acreage increases by 1%. The scale elasticity of rice is 0.0325, implying rice acreage increases by 0.0325% when total crop acreage increases by 1%. The scale elasticity of oat is -0.0097, implying oat acreage decreases by 0.0097% when total crop acreage increases by 1%.

CONCLUSION

In the middle of the controversy related to policy decisions as to biofuels expansion, the most central issue could be whether or not the U.S. agricultural industry can produce enough product to simultaneously satisfy both traditional food and feed demand and still meet the demand for bio-fuels. This challenge placed on the U.S. agricultural industry may be met with a long-term, rather than short-term, strategy in mind; particularly because demand for biofuels is much greater than what U.S. agriculture can satisfy in the short term. Excess demand for corn, as a major source for bioethanol, requires a marked increase in corn production. Given the limited availability of land, it requires adjustment of land use for additional corn production for bioethanol. This will inevitably reduce available land to produce traditional food and feed crop production. This is the case in the light of increasing market demand and favorable government policies promoting bioethanol production from corn. In this environment, acreage for less economically profitable crops will be reduced.

The purpose of this study was to determine the price response of individual crops during the past four decades in order to anticipate the impacts stemming from an expansionist bioethanol policy. In so doing, this study attempted to provide an economic foundation through the use of a traditional Rotterdam demand system. Then, using the Rotterdam demand system, this study estimated own- and cross-acreage elasticities and scale elasticities to demonstrate the impacts of acreage values on crop production and the relationship between total cropland and individual crop acreage.

All crops studied herein showed an inelastic acreage response, implying that crop acreage is insensitive to a change in acreage value. In particular, rice farming is most inelastic to own acreage value. All cross acreage elasticities are shown to be negative, implying that individual cropland types are substitutes for each other. For corn, soybeans, hay, and wheat are shown to be highly substitutable crops while cotton, sorghum, barley, rice, and oats exhibited a lesser degree of substitutability. In this study, corn, soybeans, hay, wheat, cotton, barley, and rice are shown to have positive scale elasticities, while sorghum and oats are shown to have negative scale elasticities. The scale effects of corn, soybeans, hay, and wheat are relatively large and the scale effects of cotton, sorghum, barley, rice, and oats are relatively small.

Footnote 1.

Arthur Lewbel (1996) provides general conditions for aggregating commodities without separable utility to include the vast number of different commodities that consumers buy. Since these conditions impose plausible restrictions on price movements of aggregated commodities, it lessens the power of an empirical demand model when the conditions needed for commodity aggregation are not satisfied.

Footnote 2.

In demand analysis, the assumption of separability is extremely useful for economic modeling because of the vast number of different commodities that exist in the real world. Moschini et al. (1994) discussed the separability assumption in building an empirical demand model. According to their study, the oft invoked separability assumption leads to the specification for conditional (second stage) demand systems. For example, it is common to model demand for meats (beef, pork, and poultry) as a function of the price of these three meat aggregates and of total meat expenditure. Such a procedure is justified if the direct utility function is weakly separable in the appropriate partition, which provides the necessary and sufficient condition for conditional demand functions to exist. However, there are at least two undesirable features associated with the empirical use of conditional demand systems. Initially, first-stage income allocation is often left unspecified, or conducted ad hoc, which makes the resulting elasticity estimates of limited value. Second, although direct weak separability guarantees the existence of a conditional demand system, econometric problems still may exist in estimation because group expenditures are endogenous. These limitations could be eschewed if weak separability restrictions were built into a full demand system.

Footnote 3.

In general, an indirect utility function is decreasing and quasi-convex in price (Varian, 1992).

Table 1. Summary Statistics for Acreage and Acreage Value of Individual Crop: 1963-2007

Crop	Acreage				Acreage Value			
	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
Corn	66987	7390	51479	86542	81.02	34.62	23.92	183.87
Soybean	58050	12595	28615	74602	90.17	36.74	30.09	215.81
Hay	61621	2078	58815	67496	84.59	39.19	22.79	175.86
Wheat	57899	8924	43564	80642	84.34	27.76	33.42	178.60
Cotton	11853	1856	7347	16006	75.76	31.20	29.44	130.67
Soughum	11381	3111	4937	16782	87.14	33.25	31.72	214.18
Barley	7883	2420	2951	11974	84.51	34.46	24.58	181.13
Rice	2686	547	1770.8	3792	81.51	28.92	32.76	136.18
Oat	8761	6052	1505	21308	88.55	33.58	32.91	178.88
Other	120894	15091	98055.48	161109.83	85.13	27.26	36.50	151.00

Acreage Value = Price*Yield (Deflated 1990-92=100)

Table 2. Elasticity Coefficients

	Corn	Soybean	Hay	Wheat	Cotton	Soughum	Barley	Rice	Oat	Other	Scale
Corn	0.12800	-0.02264	-0.02260	-0.02247	-0.00286	-0.00356	-0.00305	-0.00132	-0.00368	-0.04582	0.05642
Soybean		0.11532	-0.02028	-0.01546	-0.00277	***-0.00063***	-0.00230	-0.00161	-0.00538	-0.04425	0.04394
Hay			0.12533	-0.02432	-0.00247	-0.00495	-0.00208	***-0.00036***	***-0.00116***	-0.04711	0.05022
Wheat				0.11969	***-0.00087***	-0.00648	-0.00498	-0.00104	***-0.00104***	-0.04303	0.05116
Cotton					0.02331	-0.00141	-0.00060	***-0.00016***	***-0.00096***	-0.01121	0.00743
Soughum						0.02401	-0.00082	***-0.00023***	***-0.00102***	-0.00491	***-0.00054***
Barley							0.01857	0.00084	***0.00053***	-0.00612	0.00592
Rice								0.00816	***0.00011***	-0.00439	0.00501
Oat									0.01513	-0.00254	***-0.00149***
Other										0.20938	0.07344

System Weighted R^2: 0.9583

Italic numbers represent statistical insignificance at 5% level

Table 3. Marshallian Elasticities

	Corn	Soybean	Hay	Wheat	Cotton	Soughum	Barley	Rice	Oat	Other	Scale
Corn	0.7751	-0.2022	-0.1995	-0.1991	-0.0281	-0.0339	-0.0266	-0.0168	-0.0322	-0.4034	0.3665
Soybean	-0.1956	0.7233	-0.1769	-0.1452	-0.0260	-0.0127	-0.0207	-0.0173	-0.0424	-0.3788	0.2855
Hay	-0.2111	-0.1937	0.8221	-0.2199	-0.0262	-0.0447	-0.0210	-0.0104	-0.0160	-0.4288	0.3263
Wheat	-0.2095	-0.1598	-0.2187	0.7753	-0.0152	-0.0551	-0.0409	-0.0151	-0.0151	-0.3990	0.3324
Cotton	-0.1546	-0.1501	-0.1366	-0.0751	0.8925	-0.0628	-0.0285	-0.0126	-0.0435	-0.5156	0.0483
Soughum	-0.1188	-0.0188	-0.1665	-0.2188	-0.0477	0.8210	-0.0277	-0.0074	-0.0344	-0.1625	-0.0035
Barley	-0.2138	-0.1721	-0.1581	-0.3150	-0.0407	-0.0536	0.9963	0.0382	0.0215	-0.4224	0.0384
Rice	-0.0927	-0.1048	-0.0479	-0.0783	-0.0128	-0.0167	0.0332	0.3567	0.0001	-0.2587	0.0325
Oat	-0.1632	-0.2386	-0.0514	-0.0461	-0.0426	-0.0452	0.0236	0.0051	0.6710	-0.1126	-0.0097
Other	-0.1980	-0.1916	-0.1999	-0.1860	-0.0455	-0.0245	-0.0259	-0.0210	-0.0145	0.6524	0.4771

REFERENCES

Barten, A.P. (1993). "Consumer Allocation Models: Choice of Functional Form." *Empirical Economics* 18:129-58.

Carlos, A., and K. David (2007). "Estimation of Area Elasticities from a Standard Profit Function." *American Journal of Agricultural Economics* 89(3):727-37.

Chambers, R., and R. Just (1989). "Estimating Multioutput Technologies." *American Journal of Agricultural Economics* 71(4):980-95.

Daniel, G.D., B.C. English, and K. Jensen. "*Sixty Billion Gallons by 2030: Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion*." Principal Paper, 2007 Joint Annual Meeting of the AAEA, WAEA, and CAFS, Portland, Oregon. July 29-August 1, 2007.

Daniel, G.D., M.E. Walsh, H. Shapouri, and S.P. Slinsky (2003). "*The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture*." USDA, Agricultural Economic Report No.816.

Energy Information Administration (2007). "*Biofuels in the U.S. Transportation Sector." Energy Information Administration*." Website: www.eia.doe.gov/oiaf/analysispaper/biomass.html accessed on December 13 2007.

Göran, G., M. Hoogwijk, and R. Broek (2003). "The Contribution of Biomass in the Future Global Energy Supply: a Review of 17 Studies." *Biomass and Bioenergy* 25:1-28.

Haden, K. (1990). "The Demand for Cigarettes in Japan." *American Journal of Agricultural Economics* 72(2):446-50.

Lewbel, A. (1996). "Aggregation Without Separability: A Generalized Composite Commodity Theorem." *The American Economic Review* 86(3):524-43.

Lynn, W. (2007). "*Historical Perspective on How and Why Switchgrass was Selected as a Model High-Potential Energy Crop*." Oak Ridge National Laboratory, ORNL/TM-2007/109.

Masami, K., M. Donald, and W. William (2007). "*Considering Trade Policies for Liquid Biofuels*." The International Bank for Reconstruction and Development, Special Report 004/07.

Meilke, K., and R. Kramar (1976). "Acreage Response in Ontario." *Canadian Journal of Agricultural Economics* 24:51-66.

Moschini, G., M. Daniele, and G.D. Richard (1994). “Maintaining and Testing Separability in Demand Systems.” *American Journal of Agricultural Economics* 76(1):61-73.

Morzuch, B.J., R.D. Weaver, and P.G. Helmberger (1980). Wheat Acreage Supply Response under Changing Farm Programs. *American Journal of Agricultural Economics* 62(1):29-37.

Simla, T., E. Amani, F. Jacinto, H.J. Dermot, B.A. Bruce, Y. Edward, D. Fengxia, H.E. Chad, and B.C. John (2007). “Long-Term and Global Tradeoffs between Bio-Energy and Food.” Selected Parer, 2007 Joint Annual Meeting of the AAEA, WAEA, and CAFS, Portland, Oregon. July 29-August 1, 2007.

Shumway, C.R., R. Saez, , and P. Gottret (1988). “Multiproduct Supply and Input Demand in U.S. Agriculture.” *American Journal of Agricultural Economics* 70(2)330-37.

USDA (2007). “*USDA Agricultural Projections to 2016*.” USDA. Interagency Agricultural Projections Committee, Projections Report OCE-2007-1.

Varian (1992). *Microeconomic Analysis* (3rd Edition). New York: W.W. Norton & Company.

Zellner, A. (1962). “An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. *Journal of the American Statistical Association* 57:348-68.