Washington Biofuel Feedstock Supply under Price Uncertainty

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Abstract:

Biofuels, as alternative transportation fuels, are now being used globally. Taking advantage of in-state feedstock supply is an efficient way to stimulate in-state biofuel industries and the local economy. This paper uses the mean-variance model of utility maximization to estimate supply equations for major biofuel feedstock crops in Washington. We consider price risk, examine the comparative statics results of the model, and use the results to draw important decision-making implications for Washington farmers who are considering production of biofuel feedstocks. Of three potential feedstock crops, only one shows immediate promise in Washington.

Keywords: biofuel feedstock, price uncertainty, supply

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Biofuels, as alternative transportation fuels derived from biomass, are now being used globally. Biofuels can provide local economic benefits such as additional markets for farm crops and additional jobs in rural communities. Broader benefits include potential mitigation of greenhouse gas emissions (under certain scenarios) as well as improvements in energy security by decreasing dependence on foreign sources of fuels.

Biofuel production and use are in their infancy but are experiencing a period of rapid growth. New markets are being created to help foster biofuel growth across the United States. Washington State's push toward biofuels is evidenced by state and local government mandates, expansion of state-owned vehicles running on biofuels, increases in the number of biofuel plants, and increases in the acreage of feedstocks.

Taking advantage of in-state feedstock supply is an efficient way to stimulate in-state biofuel industries and the local economy. Thus, analyzing the existing feedstock supply and potential in Washington is important. "Under current technology, Washington's potential biofuel crops include corn and sugar beets for sugar-based ethanol; oilseed crops (canola, soybeans, camelina, mustard, safflower, sunflower and peanuts) for biodiesel; and poplar, grain straw, switch grass and other fiber sources for cellulosic ethanol." (Yoder et. al., 2007, p. 7)

Corn ethanol is the major biofuel now used in the United States. In Washington, corn is primarily grown under irrigation in the Columbia Basin. It is relatively expensive to grow corn in Washington compared to the Midwest. Although there was a 67% increase in Washington corn harvested acreage in 2007 compared to 2006, it contributes a trivial part of national production (about 1/10 of 1 percent). Sugar beets were a common crop produced in Washington until 1978, but little has been grown since processing facilities were closed due to low sugar prices and high energy costs. The very few acres of sugar beets still grown in Washington are near Moses Lake, and research on the economic potential for sugar beets as a biofuel feedstock is necessary and underway.

Compared to their mature experience in growing grains, oilseed crops are comparatively new to Washington's farmers. Economic viability and agronomic refinements to plant and harvest techniques, nutrient inputs, soil management, and weed and pest control are just beginning (Washington State Biofuels Advisory Committee Report. August 2007). Canola has the highest oil yield of the various oilseed crops and has been grown in limited quantities for several decades in Washington. Mustard and safflower have lower oil yields than canola. Soybeans can be grown in the warmer southern portion of the Columbia Basin but only under irrigation. Camelina, sunflower and peanuts are under cropping trials in the State.

The final type of biofuel feedstock is cellulosic biomass, inedible plants grown on less than optimal farmland. Use of cellulosic feedstock will mitigate the food versus fuel problem but will take time for producers to gain experience to grow and for researchers and processors to innovate with improved technologies to convert cellulose to fuel. We do not consider cellulosic feedstock supplies in this paper.

With more farmers considering production of biofuel feedstocks, an examination of their supply response is critical for purposes of predicting future crop prices as well as food and fuel supplies. The high demand for biofuel production that may or may not persist could drive feedstock prices to be high and variable which will play an important role in farmers' planting decisions. Thus, the analysis of biofuel feedstock supplies must take crop price uncertainty into account.

Much research has focused on crop supplies. Some studies have incorporated price or output risk into the economic models of supply. This paper follows the mean-variance model of utility maximization and emphasizes the supply of major biofuel feedstocks in Washington under price uncertainty. Its purpose is to predict supply response and guide Washington farmers in making optimal production decisions as the biofuel industry develops in the State. Our objectives are to (a) estimate supply equations for major biofuel feedstock crops under price risk, (b) examine the comparative statics results of the model, and (c) use the results to draw important decision-making implications for Washington farmers who are considering production of biofuel feedstocks.

Relevant Literature

The research literature on crop supplies under risk is extensive. We will illustrate the extent of this literature by citing just a few and will give relatively greater emphasis to literature that has addressed both profit and risk motives.

Just (1974) generalized the adaptive expectations geometric lag model by including quadratic lag terms indicative of risk and applied the model to the analysis of California field-crop supply response. Pope (1982) addressed conceptual and estimation issues to develop procedures for incorporating risk into a wide range of production economic models and procedures.

Chavas and Holt (1990) developed an acreage supply response model under expected utility maximization considering price and yield uncertainty using subjective probability distributions and investigated its empirical implications for U.S. corn and soybean acreages. Pope and Just (1991) proposed an econometric test for distinguishing the class of preferences and implemented it for potato supply response in Idaho. Meyers and Robison (1991) extended the theory of the firm facing a random output price to include industry equilibrium conditions and developed a single aggregate model under risk which displays the linkages between risk, return and land prices. Coyle (1992) developed tractable dual models of production under risk aversion and price uncertainty within the context of a mean-variance model of utility maximization. Saha, Shumway and Talpaz (1994) used an expo-power utility function to jointly estimate risk preference structure, degree of risk aversion and production technology and implemented it for a sample of Kansas wheat farmers. Chavas and Holt (1996) developed a maximum likelihood procedure to jointly estimate risk preferences and technology under very general conditions and used it to examine U.S. corn-soybean acreage decisions.

Saha and Shumway (1998) derived the complete set of refutable propositions for the competitive firm model under a general wealth structure that encompasses price and output risk as special cases and empirically tested some of the propositions using firm-level data. Adrangi and Raffiee (1999) developed a general model of the competitive firm's behavior under output and factor price uncertainty to evaluate the role of market interdependencies in analyzing long-run equilibrium conditions and the comparative statics of increased uncertainty in output and input prices. Kumbhakar (2002) dealt with specification and joint estimation of risk preferences, production risk, and technical inefficiency. Alghalith (2007) modified and expanded the duality theory and implemented a tractable empirical procedure for estimating supply response and testing hypotheses under both price and output uncertainty.

In this study, we will consider both price and risk motivations in our model of expected utility maximization. We will also consider both price risk of the feedstock commodity as well as the influence of price risk from rotational crops to estimate the optimal supply response.

Data

The primary biofuel feedstock crops currently being grown in Washington or being given serious consideration by farmers are corn, sugar beets and canola. State-level annual data for these crops and their primary rotational crops are used in the analysis. We consider three rotational pairs – corn and potatoes, sugar beets and alfalfa hay, canola and wheat. The production data for corn, potatoes and alfalfa hay and the market price data for potatoes and alfalfa hay for Washington from 1960 to 2006 are from the USDA National Agricultural Statistics Service. The production data for sugar beets, market price data and government program payments for corn and sugar beets, and aggregate input price index data for Washington from 1960 to 2004 were compiled by Eldon Ball. Then we derived these data for 2005 and 2006 from USDA NASS data and Eldon Ball's government program payments data.

Since time series data for U.S. and state-level canola production do not exist for this length of time, we use annual data for four states from 1992 to 2004. State-level production, market price, government program payments and aggregate input price index data for canola and wheat for Washington, Idaho, Minnesota and North Dakota are from Eldon Ball. Research stock data for each state for the period 1961-2004 were compiled by Wallace Huffman.

Method of Analysis

We estimate supply equations for three pairs of crops commonly grown in rotation in Washington. They include corn and potatoes, alfalfa hay and sugar beets, wheat and canola. We have enough observations for corn, potatoes, alfalfa hay and sugar beets to introduce price risk along with profit into an expected utility function. Farmers are expected to be risk averse and maximize the expected utility of profit and uncertainty. We use Model 1 to derive the supply functions for these two pairs of crops.

Because of limited data for canola, we use panel data and estimate supply equations for canola and wheat based on profit maximization using a multi-state panel model, Model 2. We use this model to focus attention on Washington supply response of canola.

Model 1

We assume farmers are risk averse and seek to maximize their expected utility after considering crop price risks. Following Coyle (1992), the mean-variance utility function with stochastic output prices is linear in expected profits, $E\pi$, and profit variance, $V\pi$, as:

$$(1) \qquad U = E\pi - \frac{\alpha}{2} V\pi$$

where α is a measure of risk aversion.

In our case, the farm manager plants two rotational crops using an aggregate input. The farmer's profit function is:

$$(2) \qquad \pi = p_1 y_1 + p_2 y_2 - wx$$

where p_1, p_2 are crop prices (market prices adjusted for government programs payments), y_1, y_2 are crop output levels, w is aggregate input price, and x is aggregate input level. Hence,

$$(3) \qquad E\pi(y_1, y_2, x) = \overline{p}_1 y_1 + \overline{p}_2 y_2 - wx$$

$$(4) \qquad V\pi(y_1, y_2, x) = y_1^2 var(p_1) + y_2^2 var(p_2) + 2 y_1 y_2 cov(p_1, p_2)$$

where $\overline{p}_1, \overline{p}_2$ are expected crop prices (including government program payments) at planting time, $var(p_1)$, $var(p_2)$, $cov(p_1,p_2)$ are variances and covariances of the crop prices.

The farmer is risk averse and maximizes her expected utility:

$$(5) \qquad \begin{aligned} &U^*(\overline{p}_1, \overline{p}_2, w, \mathrm{var}(p_1), \mathrm{var}(p_2), \mathrm{cov}(p_1, p_2)) \\ &= \max_{y_1, y_2, x} \left\{ U(y_1, y_2, x) = \overline{p}_1 y_1 + \overline{p}_2 y_2 - wx - \frac{\alpha}{2} \left[y_1^2 var(p_1) + y_2^2 var(p_2) + 2 y_1 y_2 cov(p_1, p_2) \right] \right\} \end{aligned}$$

The following propositions apply to this dual specification of the price taking, risk averse, expected-utility maximizing producer:

(a) U^* is increasing in $\overline{p}$, decreasing in w, decreasing in Vp, where Vp is the covariance matrix of crop prices.

(b) U^* is linear homogeneous in $(\overline{p}, w, Vp)$.

(c) U^* is convex in prices $\overline{p}$ and w.

(d) $U^*(\cdot)$ is differentiable as follows:

(6) $$\frac{\partial U^*(\overline{p}, w, Vp)}{\partial \overline{p}_j} = y_j^*, j = 1,2.$$

(7) $$\frac{\partial U^*(\overline{p}, w, Vp)}{\partial w} = -x$$

(8) $$\frac{\partial U^*(\overline{p}, w, Vp)}{\partial Vp_{jj}} = -\frac{\alpha}{2} y_j^{*2}, j = 1,2.$$

(9) $$\frac{\partial U^*(\overline{p}, w, Vp)}{\partial Vp_{ij}} = -\alpha y_i^* y_j^*, i \neq j; i, j = 1,2.$$

By specifying functional forms for the derivatives of this dual model with respect to prices $\overline{p}$ and w, we can get specific functional forms for the derivatives of the dual with respect to the elements of Vp, and can trace backwards to the dual utility function by Euler's theorem.

First we define general forms for the partial derivatives.

(10) $$\begin{aligned} y_j &= y_j\left(\frac{\overline{p}_1}{w}, \frac{\overline{p}_2}{w}, \frac{\text{var}(p_1)}{w}, \frac{\text{var}(p_2)}{w}, \frac{\text{cov}(p_1, p_2)}{w}\right), j = 1,2. \\ x &= x\left(\frac{\overline{p}_1}{w}, \frac{\overline{p}_2}{w}, \frac{\text{var}(p_1)}{w}, \frac{\text{var}(p_2)}{w}, \frac{\text{cov}(p_1, p_2)}{w}\right) \end{aligned}$$

Since we do not have input quantity data for our specific crops, we are unable to estimate the input demand equation. Using seemingly unrelated regression method (SUR), we estimate the following system of supply functions, which are generalizations of those derived from a normalized quadratic profit function:

$$(11)\qquad \begin{aligned} y_{1t} &= a_1 + a_{11}\frac{p_{1t-1}}{w_t} + a_{12}\frac{p_{2t-1}}{w_t} + a_{13}R + b_{11}\frac{\text{var}(p_{1t})}{w_t} + b_{12}\frac{\text{var}(p_{2t})}{w_t} + b_{13}\frac{\text{cov}(p_{1t}, p_{2t})}{w_t} \\ y_{2t} &= a_2 + a_{21}\frac{p_{1t-1}}{w_t} + a_{22}\frac{p_{2t-1}}{w_t} + a_{23}R + b_{21}\frac{\text{var}(p_{1t})}{w_t} + b_{22}\frac{\text{var}(p_{2t})}{w_t} + b_{23}\frac{\text{cov}(p_{1t}, p_{2t})}{w_t} \end{aligned}$$

where R is the state level research stock variable. Assuming a Markov process, farmers take each crop's lagged price (adjusted for government payments) as the expected price. Consistent with proposition (b) of the utility function, this specification maintains the property that each supply function is homogeneous of degree zero in prices, variance, and covariance by dividing each of these variables by the input price index. Consistent with property (c), we maintain the property that the system of supply functions is convex in prices by reparameterizing the parameter matrix on the price variables using the Cholesky decomposition method. Consistent with property (d), we impose symmetry restrictions on the cross-price equations.

Empirically, we need to derive variances and covariances of the crop prices. We follow the method developed by Chavas and Holt (1996) and calculate the current variance and covariance as the sum of squares of prediction price errors of the last three years with declining weights.

$$(12)\qquad \text{var}(p_j) = \sum_{k=1}^{3} \omega_k (p_{jt-k} - E_{jt-k} p_{jt-k})^2 \quad j = 1,2.$$

$$(13)\qquad \text{cov}(p_1, p_2) = \sum_{k=1}^{3} \omega_k (p_{1t-k} - E_{1t-k} p_{1t-k})(p_{2t-k} - E_{2t-k} p_{2t-k})$$

where ω_k are 0.5, 0.33, 0.17, respectively, when $k=1,2,3$.

We also introduce two dummy variables in the sugar beets supply equation. Sugar beets production in Washington changed abruptly on three occasions during our data period – in 1978 when the U&I Sugar Company closed its sugar processing plant, in 1994 when the Moses Lake plant began to operate, and in 2000 when it closed. To account for the influence of these external changes, we introduce two dummy variables in the sugar beets supply function. Dummy variable

d_1 takes a value of 1 for the 1979-2006 period, 0 otherwise. Dummy variable d_2 takes a value of 1 for the period 1994-2000, 0 otherwise.

We report and analyze the estimation results both under risk neutrality (i.e., when b_{ij}=0, /.i=1,2; j=1,2,3 in equation (11)) and when we include the price variance and covariance items. We test for risk neutrality by testing the hypothesis that the coefficients on the variance and covariance terms are jointly zero. We also report own price and cross price supply elasticities and analyze the decision making and policy implications.

Model 2

We use panel data and estimate supply equations for canola and wheat based on profit maximization in a multi-state panel model. Because of the extremely limited time series for canola price and production data in each state, we do not introduce price risk into the supply functions but maintain the assumption of linear supply functions. Under price-taking, profit-maximizing behavior, the supply equations are nondecreasing in output prices, nonincreasing in aggregate input price, homogeneous of degree zero in prices, and convex in prices. If the profit function is twice continuously differentiable, the cross-price parameters are symmetric between the linear supply functions. Thus, we estimate the following supply functions as a fixed-effect panel data model allowing for differences between states in all parameters:

$$(14)\quad \begin{aligned} y_{1mt} &= a_{1m} + a_{11m}\frac{p_{1mt-1}}{w_{mt}} + a_{12m}\frac{p_{2mt-1}}{w_{mt}} + a_{13m}R_{mt} \\ y_{2mt} &= a_{2m} + a_{21m}\frac{p_{1mt-1}}{w_{mt}} + a_{22m}\frac{p_{2mt-1}}{w_{mt}} + a_{23m}R_{mt} \end{aligned}$$

where m=*WA, ID, MN, ND* denotes Washington, Idaho, Minnesota, and North Dakota, respectively.

We also estimate this system of supply equations as a system of seemingly unrelated regressions. While we obtain results for all four states, we focus on the implications for Washington.

We apply both of these models to state-level data. Depending on the model, we maintain the hypothesis that each state acts as though it were an expected utility (or profit) maximizing producer. While this is an important abstraction from reality, Lim and Shumway's (1992) nonparametric test results failed to reject the more binding of these two hypotheses for Washington.

Results

Parameter estimates for the corn and potatoes supply functions are reported in Table 1 both under risk neutrality and when considering price risk. Under risk neutrality, all the parameter estimates are statistically significant at the 5 percent level. They also render statistically significant own-price and cross-price elasticities at the data means. Although each of the supply elasticities is statistically significant, the corn own-price elasticity is trivial while the potato own-price elasticity is very large. The cross-price elasticities are positive, implying the two crops are complements. They are also very small, but corn supply is more dependent on potato price than corn price. Although the magnitudes of both the corn and potato own-price elasticity estimates are so extreme as to be outside the range of thoughtful practicality, when considered along with the cross-price elasticities, they do reflect one important point. Corn is a very low-value crop relative to potatoes and is often grown as a rotation crop with potatoes. Thus, it is expected potatoes price that drives the production of potatoes. And, since they are grown in rotation, it also drives the production of corn.

We next examine whether price risk is statistically significant and whether it moderates the supply elasticity estimates. When supply response is couched within the framework of maximizing expected utility, nearly all the parameter estimates of the expanded model are significant. The only exceptions are the intercept, variance of potato price, and price covariance in the corn supply equation. Each of the elasticity estimates is statistically significant. The extreme values of the elasticity estimates estimated under risk neutrality are moderated under expected utility maximization, but only a little. The corn elasticity remains trivial and the potato elasticity remains very large. The hypothesis of risk neutrality is rejected, which implies that the expected utility maximization framework is preferred to the assumption of profit maximizing behavior. However, under both maintained hypotheses, our assessment of the historical data suggests that Washington corn is unlikely to become a major source of biofuel feedstock.

Table 2 provides the estimation results for alfalfa hay and sugar beets supply equations both under risk neutrality and when considering price risk. Under risk neutrality, most parameter estimates are significant at the 5 percent level. The only exceptions are the alfalfa hay price in the alfalfa hay supply equation and the sugar beets price and the first dummy variable in the sugar beets supply equation. The alfalfa hay own-price elasticity and sugar beets own-price elasticity are not significant at the 5 percent level, but they are significant at the 10 percent level. The cross-price elasticities are positive and significant at the 5 percent level indicating that these two crops are complements.

When risk is considered, most parameter estimates in the alfalfa hay supply equation are not significant. The price variance and covariance terms in the sugar beets supply function are also not significant. Since the price covariance terms were insignificant in both supply functions, we dropped them and re-estimated the supply equations only considering price variance. Nearly all parameter estimates and elasticities are now significant. The only exceptions are research investment and sugar beets price variance in the alfalfa hay supply. All elasticity estimates under price risk are larger than those under risk neutrality. This is especially true for the own-price elasticities. The hypothesis of risk neutrality was rejected in favor of expected utility maximization. The large own-price elasticity estimates for sugar beets suggest that this crop has potential to become a major biofuel feedstock in Washington. Further, its supply can be encouraged by an increase in the market price and/or the government subsidy.

The parameter estimates for Washington, Idaho, Minnesota, and North Dakota wheat and canola supply equations are reported in Table 3. Only 10 of the 28 parameter estimates are significant. They include the own-price parameter for wheat in WA, ID, and ND, the own-price parameter for canola in MN, and the canola-wheat cross-price parameter in ND. Elasticity estimates at the data means are reported in Table 4. The only significant elasticity in Washington, is the wheat own-price elasticity. The canola own-price elasticity is economically trivial as well as statistically insignificant. The cross-price elasticity is positive which implies wheat and canola are complements, but it is insignificant. Qualitative results for Idaho are the same as for Washington and estimated elasticity magnitudes are similar. Results for Minnesota and North Dakota are quite different. In Minnesota, all estimated elasticities are larger, wheat and canola are substitutes, but only the canola own-price elasticity is significant. Although North Dakota produced more than 90% of the U.S. canola crop in 2004, only its cross-price elasticities and wheat own-price elasticity were significant. In this state wheat and canola are substitutes and canola production is much more sensitive to wheat price rather than its own price.

Washington contributed 0.35% of the U.S. canola production and 6.65% of U.S. wheat production in 2004. The State's canola supply is trivial and our analysis suggests that it currently is largely unresponsive to its expected price. Other recent empirical evidence supports this finding by noting that high production risks associated with producing this crop in Eastern

Washington make it uncompetitive with other crops (Zaikin, Young, and Schillinger 2007). Thus, the evidence from both econometric analysis and production trials suggests that, despite its high oil yield for biodiesel, Washington-produced canola is unlikely to be a major source of biofuel feedstock in the near future.

Decision Making and Policy Implications

From above empirical results, we know that in Washington State, corn is unlikely to become a major source of biofuel feedstock, sugar beets has large potential whose supply can be encouraged by price and subsidy, canola is hard to judge due to the limited quantity and variability. Under current legislature, Washington State's Renewable Fuel Standard requires certain licensees in the fuel production chain to report evidence that at least two percent of gasoline and diesel in Washington State contain ethanol or biodiesel respectively by December 2008 (RCW 19.112.110, RCW 19.112.120). For example, for a 2.7 billion gallons gasoline market, this implies 54 million gallons biofuel requirements. Currently there is virtually no use of Washington biomass for biofuel production (Yoder et. al., 2007). If we want to reach the goal to use in-state feedstock to satisfy part of the biofuel production demand, an increase in the price or subsidy for sugar beets could increase its supply substantially.

According to University of Missouri Food and Agricultural Policy Research Institute 2006 Report (FAPRI-UMC Report #02-06), in 2012, 1 ton of sugar beets can convert to 24 gallons of ethanol. Thus if we suppose that in-state sugar beets can convert to 10% of in-state biofuel demand, i.e. 5,400,000 gallons ethanol, then we need 225,000 tons more sugar beets production which is 3 times of Washington 2006 sugar beets production. Thus we need to double sugar beets price to get this.

Conclusions

In this paper, we estimated supply equations for corn, sugar beets and canola in Washington State under expected utility maximization framework considering the crops own and rotational crops prices and risks. Examining the comparative statics results of the model, we conclude that corn and canola are not likely to become major sources of biofuel feedstock in Washington, sugar beets has some potential and the supply can be encouraged by an increase in the market price and/or the government subsidy. If we suppose that in-state sugar beets can convert to 10% of in-state biofuel demand, we need to double sugar beets price.

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Table 1. Estimated Washington Corn and Potatoes Supply Equations

Parameter (Equation 11) [a]	Risk-Neutral Equations		Equations with Risk	
	Coefficient	P-value	Coefficient	P-value
a_1	-11492	0.00000	-8734.6	0.00000
a_{11}	0.20654E-01	0.00000	0.19459	0.01217
$a_{12} = a_{21}$	21.448	0.00001	99.192	0.01966
a_{13}	0.80824	0.00000	0.74020	0.00000
a_2	-669.93	0.00000	-402.82	0.00000
a_{22}	0.32852E+06	0.01221	0.27680E+06	0.00066
a_{23}	2.6896	0.00000	2.7172	0.00000
b_{11}	—	—	-6301.5	0.00000
b_{12}	—	—	1027.9	0.22499
b_{13}	—	—	-1683.2	0.00000
b_{21}	—	—	-2462.8	0.00000
b_{22}	—	—	-1995.0	0.00000
b_{23}	—	—	-1819.2	0.00000
Corn own price elasticity	0.70471E-05	0.00000	0.66392E-04	0.01217
Corn cross price elasticity	0.88086E-02	0.00001	0.40738E-01	0.01966
Potatoes own price elasticity	27.171	0.01221	22.894	0.00066
Potatoes cross price elasticity	0.14737E-02	0.00001	0.68156E-02	0.01966
Test of risk neutrality	—		reject	

[a] Parameters with a first subscript of 1 are from the corn equation, and those with a first subscript of 2 are from the potatoes equation.

Table 2. Estimated Washington Alfalfa Hay and Sugar Beets Supply Equations

Parameter (Equation 11) [a]	Risk-Neutral Equations		Equations with Risk			
			Including Variance and Covariance		Including Variance Only	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
a_1	101.41	0.00000	100.14	0.00000	100.15	0.00000
a_{11}	1.0998	0.08841	2.8123	0.54190	2.9736	0.04401
$a_{12} = a_{21}$	3.7755	0.00582	6.2044	0.40832	3.9158	0.00066
a_{13}	0.55281E-01	0.00000	0.56487E-01	0.10171	0.59194E-01	0.00000
a_2	100.24	0.00000	100.03	0.00000	100.03	0.00000
a_{22}	15.748	0.06203	23.625	0.00000	24.425	0.00001
a_{23}	-0.31826E-01	0.00370	-0.25700E-01	0.01405	-0.16963E-01	0.05665
c_1	8.1891	0.12214	9.8986	0.00000	9.7607	0.00000
c_2	10.93	0.00016	10.050	0.00000	10.082	0.00000
b_{11}	—	—	-1.2179	0.16266	-1.4843	0.00000
b_{12}	—	—	-1.3268	0.22030	-0.69849	0.10791
b_{13}	—	—	0.53947	0.86233	—	—
b_{21}	—	—	-2.0167	0.05027	-2.8892	0.00000
b_{22}	—	—	2.9568	0.23115	2.1984	0.00342
b_{23}	—	—	-1.9725	0.30735	—	—
Alfalfa hay own price elasticity	0.50058E-01	0.08841	0.12800	0.54190	0.13535	0.04401
Alfalfa hay cross price elasticity	0.80598E-01	0.00582	0.13245	0.40832	0.83592E-01	0.00066
Sugar beets own price elasticity	0.94162	0.06203	1.4126	0.00000	1.4604	0.00001
Sugar beets cross price elasticity	0.48132	0.00582	0.79096	0.40832	0.49920	0.00066
Test of risk neutrality	—		reject		reject	

[a] Parameters with a first subscript of 1 are from the alfalfa hay equation, and those with a first subscript of 2 are from the sugar beets equation.

Table 3. Estimated WA, ID, MN, ND Wheat and Canola Supply Equations

Parameter (Equation 14) [a]	Coefficient	P-value	Parameter (Equation 14)[a]	Coefficient	P-value
a_{1WA}	0.41690E+06	0.00509	a_{13MN}	0.17842E+06	0.04559
a_{1ID}	48679	0.38366	a_{13ND}	-0.43532E+06	0.48308
a_{1MN}	-0.11795E+06	0.30846	a_{2WA}	-23239	0.78168
a_{1ND}	0.50992E+06	0.26207	a_{2ID}	-38575	0.64299
a_{11WA}	22377	0.00131	a_{2MN}	-10108	0.81727
a_{11ID}	15763	0.04332	a_{2ND}	0.17169E+07	0.00000
a_{11MN}	15199	0.22430	a_{22WA}	0.25112E-05	1.00000
a_{11ND}	36353	0.00938	a_{22ID}	0.35992E-05	1.00000
$a_{12WA}= a_{21WA}$	12686	0.78649	a_{22MN}	0.50307E+07	0.03713
$a_{12ID}= a_{21ID}$	25949	0.46416	a_{22ND}	0.26301E+07	0.45196
$a_{12MN}= a_{21MN}$	-87665	0.17322	a_{23WA}	4263.8	0.95017
$a_{12ND}= a_{21ND}$	-0.61616E+06	0.00000	a_{23ID}	-46316	0.45513
a_{13WA}	-0.34630E+06	0.03414	a_{23MN}	-60850	0.30179
a_{13ID}	-3840.0	0.97469	a_{23ND}	0.21675E+07	0.00000

[a] Parameters with a first subscript of 1 are from the wheat equation, and those with a first subscript of 2 are from the canola equation.

Table 4. Estimated WA, ID, MN, ND Wheat and Canola Supply Elasticities

State	Elasticity	Value	P-value	State	Elasticity	Value	P-value
WA	Wheat own price	0.10790	0.00131	MN	Wheat own price	0.81754E-01	0.22430
	Wheat cross price	0.17963E-02	0.78649		Wheat cross price	-0.12877E-01	0.17322
	Canola own price	0.21018E-12	1.00000		Canola own price	0.43679	0.03713
	Canola cross price	0.36157E-01	0.78649		Canola cross price	-0.27874	0.17322
ID	Wheat own price	0.78893E-01	0.04332	ND	Wheat own price	0.23096	0.00938
	Wheat cross price	0.41748E-02	0.46416		Wheat cross price	-0.10718	0.00000
	Canola own price	0.34228E-12	1.00000		Canola own price	0.27042	0.45196
	Canola cross price	0.76767E-01	0.46416		Canola cross price	-2.3140	0.00000