Estimating the Supply of Corn Stover at the Farm Level for Biofuel Production: Taking Account of Farmers' Willingness to Harvest

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014

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Introduction

Enhancement of the biofuel industry and advancement of biofuel production continues to be the focus of government policies. The Renewable Fuel Standard 2 (RFS2) under The Energy Independence and Security Act of 2007 requires that by 2022, 36 billion gallons of biofuel be produced in the United States, and that any new biofuels produced after 2016 must originate from cellulosic feedstock. Additionally, the Biomass Research and Development Act of 2000 calls for 30% of petroleum use to be replaced by biomass products by the year 2030 (U.S. Department of Energy 2003). While the policy requirements for biofuel productions have been increasing over time, securing an adequate supply of bioenergy feedstock is still a work in progress. Continued research is necessary for not only assessing supply potential of cellulosic feedstock but also for examining institutional arrangements that can support development of sustainable market.

Many studies have assessed the technical feasibility of producing bioenergy crops on agricultural lands (Gallagher et al., 2003; Walsh et al., 2003; Perlack et al., 2005; Graham et al., 2007; Larson, English, and Lambert, 2007; Nelson et al., 2010). These studies have determined that sufficient quantities of crop residues exist for biofuel production necessary to reach the goals mandated by policy. However, while the potential for producing large quantities of agricultural biomass for bioenergy from lignocellulosic feedstocks has been identified, many of these studies have not assessed farmers' actual willingness to harvest crop residues. Large, commercial-scale production of these advanced fuels will require well-functioning markets, which are presently either nonexistent or underdeveloped. Therefore, more research focusing on examination of various coordination mechanisms and governance structures for selling and buying biomass is still needed.

Due to the nature of the transaction between farmers and biomass processors contracting arrangements are likely to be used as a coordination mechanism. Contracts are important for bioenergy crop production, because farmers are less likely to enter into new cropping plans without contracts, and biorefineries will find it difficult to finance their plants without contracts in place (Rajagopal et al., 2007). Contractual arrangements between farmers and biomass processers will be affected by wide range of factors including contract pricing, timeframe, acreage commitments, risk, timing of harvest, yield variability, feedstock quality, harvest responsibilities, nutrient replacement, location of biorefineries, available cropping choices, technology, and conservation considerations (Larson, English, and Lambert, 2007; Epplin, Clark, Roberts, and Hwang, 2007; Wilhelm et al., 2004).

Farmers in the Great Plains region of the U.S. may be well-situated for supplying certain biomass feedstocks for second generation biofuels. Potential cellulosic feedstocks include corn stover, wheat straw, energy sorghum, switchgrass, and miscanthus. An important question is under what conditions farmers will contract their production, and what the design of these contracts will be. The purpose of this paper is to estimate the supply of potential corn stover that could be harvested taking into account farmers' willingness to harvest corn stover under alternative contractual, pricing, and harvesting arrangements. The specific objectives are: i) estimate the probability of farmers' willingness to harvest corn stover under contract in Kansas, ii) estimate the supply potential of corn stover in Kansas; and (iii) examine the impact of different contract and market attributes on adoption. The paper proceeds as follows: description of methods including data and analysis, discussion of results, and presentation of conclusions and unresolved issues.

Data and Methods

This section of the paper is split into two primary sections: (i) farmers' willingness to harvest corn stover and estimation of corn stover supply. The accompanying data and methods for each subsection are presented accordingly.

Farmers' Willingness to Harvest Corn Stover

Producer Survey

A survey was administered from November 2010 to February 2011 by Kansas State University and the USDA, National Agricultural Statistics Service (NASS) to assess farmers' willingness to produce cellulosic biomass in the form of corn stover, sweet sorghum, and switchgrass for bioenergy production under different contractual arrangements. A total of 485 farmers were contacted in northeastern, south central, and western Kansas to participate in the survey. These areas of Kansas were selected based on the number of farms growing corn and sorghum; proximity to future potential cellulosic bio-refinery locations; differences in climatic conditions; and use of irrigation.

In each area, a random sample of approximately 160 farms with 260 or more acres and a minimum of $50,000 in gross farm sales were selected from USDA-NASS's farmer list. The sampling requirements were set to target only commercial farms that will be more likely to produce cellulosic biomass. Potential participants were mailed a four page flier asking for their participation in the survey and providing information about cellulosic biofuel feedstock production. Willing participants were then contacted by and met with USDA-NASS enumerators to complete the survey. Of the 485 farmers contacted, 290 completed the survey and 38 were out-of-business, did not farm, or could not be located, giving a response rate of 65 percent. Further, a few surveys were found to be unusable when analyzing each stated choice experiment due to an incomplete or irregular response. The survey included questions about farmers' farming operations; willingness to produce feedstocks under contract; biofuel feedstock production preferences and perceptions; on-farm conservation practices; risk management practices and perceptions; crop marketing practices; and demographics.

Comparing farmer demographics from the survey to those in the 2007 U.S. Census of Agriculture for the state of Kansas indicates that the average age of the farmers surveyed (55.1 years) and average market value of agricultural products ($200,000 to $399,999) matches closely with statistics reported in the 2007 Agricultural Census. Average farm size in the survey though is slightly larger, likely due to the selection criteria utilized (National Agricultural Statistics Service, 2007).

To gauge farmers' willingness to harvest corn stover, a stated choice experiments was conducted. The stated choice experiment was designed to assess farmers' willingness to enter into a contract with a bio-refinery or other biomass processor for producing corn stover, sweet sorghum and switchgrass, following Louviere *et al*. (2000) and Roe *et al*. (2004). Farmers where presented with information about the production of corn stover potential contract attributes before answering the stated choice questions. For each feedstock experiment, survey participants where asked to consider 5 independent choice sets, where they were asked to select between two biomass contracts or an "opt out" option resulting in three contract options for each feedstock choice set (see Figure 1 for an example scenario). The contract attributes (and levels) included: (1) the average annual expected net return from corn stover production ($0, $10, $20, $30); (2)

length of the contract (2,5 and 8 years); (3) the option to have the biorefinery harvest the stover (yes or no); and (4) the option for the refinery to pay the farmer for nutrients lost from stover removal (yes or no). Each choice set presented to a respondent asked them to select between Contract A, Contract B, or a “Do Not Adopt” option (C). Further analysis of other survey results is provided in Fewell et al. (2013). The experimental design of the stated choice experiment followed Louviere *et al*. (2000), using a collective factorial design to allow identification of all main effects and potential interaction effects between contract attributes and levels. A $(2^3 \times 3 \times 4)^2$ was used to design the choice sets for the corn stover experiment. PROC OPTEX in SAS was used to develop the fractional factorial design for each experiment from the collective factorial to obtain 90 random choice sets, which were then blocked into 18 blocks of 5 choice sets each.[1] The *D*-optimality criterion was used to obtain an optimal design using a modified Federov search algorithm (Nguyen and Miller, 1992). Optimal blocking was determined following the method outlined in Cook and Nachtsheim (1989). Further details concerning the survey design and results are available from Fewell *et al*. (2013) and Bergtold *et al*. (2014).

Empirical Model

Following Roe *et al*. (2004), we assume that producers want to maximize expected discounted utility when choosing to adopt a contract to produce a cellulosic feedstock. Let producer *j*’s expected discounted utility for contract option *i* be given by:

$$V_{j,i} = V\left(R_i, B_i, G_i, E_{j,i}\right) + \varepsilon_{j,i} \,, \qquad (1)$$

where R_i is the net returns from harvesting corn stover; B_i is a variable indicating if a biomass harvest option is part of contract *i*; C_i is the length of the contract in years; G_i is the presence of a nutrient replacement option; and $E_{j,i}$ is a vector of error components included to account for choice situation invariant variation. It is assumed that all $E_{j,i}$ are mean zero with variance equal to one (Bhat, 1998; Greene, 2007). The error term, $\varepsilon_{j,i}$ represents the nonsystematic part of expected utility that is unobserved by the modeler and is distributed with respect to type I extreme value (Louiviere *et al.,* 2000).

The econometric model adopted is based upon a main effects model with error components following Bhat (1998). The reduced-form representation of expected utility for equation (1) (Roe *et al*., 2004), for producer *j* and contract *i*:

[1] The version of software used was SAS 2008. Windows, Version 9.2. SAS Institute, Inc., Cary, NC.

$$V_{j,i} = \beta_0 + \beta_1 R_i + \beta_2 C_i + \beta_3 G_i + \gamma_1 W_i + \gamma_2 C_i + \sum_j \theta_j E_{j,i} + \varepsilon_{j,i},\ j{=}A,B,C, \quad (2)$$

where θ_j represents the standard deviation of the error component or random effect associated with $E_{j,i}$. The additional variables W_i and C_i represent regional dummy variables equal to 1 if a producer is from western (W) or Central (C) Kansas, respectively. The inclusion of the regional dummies is to capture differences in cultural practices, climate and farmer demographics across different regions of Kansas. The error components allow the model to capture correlations among contract options and between the alternative choice scenarios facing a respondent (Greene, 2007 and 2012). For the "opt out" option in each choice scenario, $\boldsymbol{\beta} = 0$ and $\boldsymbol{\gamma} = 0$, thus, $V_{O,i} = \theta_O E_{O,i} + \varepsilon_{j,i}$, where O designates the option to not adopt or opt out. The econometric models is estimated using NLOGIT 4.0 using simulated maximum likelihood with 1000 Halton draws using the BFGS Quasi-Newton Algorithm (Greene, 2007).

Corn Stover Supply

This subsection examines the estimation of corn stover supply in a number of sections that outline the approach adopted in the paper. A significant advantage of this approach is that is easily scalable and provides a method for incorporating the probability of farmers adopting, going beyond just potential corn stover supply. All analysis is conducted at the county level and then aggregated up to the state level. This allows for analysis at both the county and state level.

Estimating Potential Corn Stover to be Harvested

A base of year of 2010 was chosen for the supply estimation. This could be readily changed to allow for analysis in different years. County level harvested corn acreage (a_k) and corn yield (y_k) were obtained from USDA-NASS for all 105 counties in Kansas (National Agricultural Statistics Service, 2012). Using Gallagher and Baumes (2012) we assume the harvest index for corn (h) is equal to 0.45 when $y_k < 112.5$ bu/ac; 0.475 when $112.5 \le y_k < 137.5$; 0.5 when $137.5 \le y_k < 162.5$; and 0.525 when $y_k \ge 162.5$. Finally we assume that farmers harvesting no-till will utilize conservation or reduced tillage practices. Thus, following Gallagher and Baumes (2012) a yield adjustment factor of 0.905 is applied to account for the moderate reduction in corn yield is applied. This data and parameters allows for the estimation of the gross yield of corn stover in lbs per acre (gs_k) for county k as:

$$gs_k = \left(\frac{1-h(y_k)}{h(y_k)}\right) y_k \times 0.905 \times 56, \quad (3)$$

where 56 is the number of pounds of stover per bushel.

Given that we assume that only farmers who practice conservation or reduced tillage will harvest corn stover (in order to protect the soil), to prevent soil erosion, farmers must at least retain 30 percent cover or 1430 pounds of crop residue on the soil surface (Gallagher *et al*., 2003; Gallagher and Baumes, 2012). Following Anand *et al.* (2011) the amount of crop residue needed for 30% ground cover is adjusted to take account of over winter decay (88% residue retention) and planter/No-till coulter usage (85% retention). These data allow for the calculation of net corn stover yield in lbs per acre (ns_k) after adjusting for the crop residue needed to meet conservation tillage requirements, i.e.:

$$ns_k = gs_k - 1430/0.88/0.85. \quad (4)$$

Of the corn land in Kansas, about 56% and 19% of the land is under conservation reduced tillage practices, respectively (KSU Research and Extension, 2010). Both of these practices can leave over 30% crop residues on the soil surface. Using this final information, we can calculate the total potential amount of available corn stover that is available to be harvested in tons in county *k* (ps_k), i.e.:

$$ps_k = \left(\frac{1}{2000}\right) ns_k \times [a_k \times (0.56 + 0.19)]. \quad (5)$$

Estimating Farmers' Willingness to Harvest Corn Stover

Using the error components logistic regression model specified using equation (2), predicted probabilities of adoption for each county (p_k) are estimated taking into account the terms of the assumed contract being offered and geographic location in the state. That is:

$$\rho_k = \frac{2\times\exp(\widehat{\beta_0}+\widehat{\beta_1}R_i+\widehat{\beta_2}C_i+\widehat{\beta_3}G_i+\widehat{\gamma_1}W_i+\widehat{\gamma_2}C_i)}{1+2\times\exp(\widehat{\beta_0}+\widehat{\beta_1}R_i+\widehat{\beta_2}C_i+\widehat{\beta_3}G_i+\widehat{\gamma_1}W_i+\widehat{\gamma_2}C_i)}, \quad (6)$$

where the multiplication by 2 results from their being two generic contract options in the choice scenarios asked in the survey. The base contract is assumed to be 2 years in length and includes both the biorefinery harvest and nutrient replacement options. The level of net returns is allowed to vary between \$0 and \$50. The amount of corn stover predicted to be harvested in county *k* (s_k) is then:

$$s_k = \rho_k \times ps_k, \quad (7)$$

which will increase as returns increase from \$1 to \$50.

Corn Stover Prices

The price of corn stover per ton in county k (P_k^s) can be estimated based on the level of net returns and the cost of harvesting the corn stover, i.e.

$$P_k^s = \left[(R_i + \$19.70) \times (a_k \times \rho_k) + s_k \times [\$1.40 + \$34.91 + \$6.55]\right]/s_k, \qquad (8)$$

where R_i is the level of return under the contract (ranging from \$1 to \$50); \$19.70 is the cost per acre of harvesting the corn stover; \$1.40 is the cost of hauling the stover per dry ton; \$6.55 is the handling costs (e.g. transport, storage) per dry ton of corn stover; and \$34.91 is the cost of nutrient replacement (N, P and K) per dry ton of corn stover removed (Gallagher and Baumes, 2012; Shearer, 2014).

Corn Stover Supply

Corn stover supply can then be determined by varying the returns (R_i) under the contract for a set of given contract attributes (i.e. by fixing the contract length, biomass refinery harvest option, nutrient replacement option). Varying returns will allow adoption rates to change, varying the amount of corn stover that will be harvested in each county. In turn, as seen in equation (8), the different level of returns implies a different price for the corn stover, as well. Plotting the quantity of corn stover harvested (supplied) (s_k) versus the price of corn stover (P_k^s), can provide an estimate of the corn stover supply curve for county k. By aggregating over the amount of corn stover harvested for each county and averaging the prices across counties (for the different levels of net returns), the supply of corn stover at the state level can be obtained.

A measure of particular interest for policy and industry is the own-price elasticity of supply for corn stover. Using the data series generated for the quantity supplied of corn stover (s_k) and the price of corn stover (P_k^s) over the varying rates of return from \$1 to \$50, an accessible method for estimating the elasticity is to assume the supply curve follows a Cobb-Douglas functional form, i.e. $\ln(s_k) = \alpha_0 + \alpha_1 \ln(P_k^s)$, where α_1 is the own-price elasticity of supply. This can be estimated using least squares and the goodness-of-fit accessed using R^2 (as it is a curve fitting exercise). This method is examined in this study.

A number of comparative statics can be examined to see how corn stover supply changes as the transaction costs under the contract increase. That is, as contract length increases or the biorefinery/nutrient replacement options are not provided under the contract. In addition, changes in the costs of production or adoption of conservation practices could be examined, as well.

Given that we can examine supply at the county level, an interesting exercise is to determine the level of return required to achieve a given level of adoption. This type of exercise may be of particular interest to a company trying to identify where to locate a cellulosic biorefinery by determining the counties that can provide a certain supply at a needed price. This problem amounts to solving the problem:

$$min_R\, Z = \left[\sum_k \rho_k(R) \times ps_k\right] / \left[\left[\sum_k \rho_k(R)\right]\right] \text{ such that } Z \geq \bar{Z}, \quad (9)$$

where $\bar{Z}$ is set by the modeler based on the required amount of corn stover needed for production. The solution to this problem will provide the supply (s_k) for each county at the minimum overall return (R). Using the optimal return from the problem, the modeler can then calculate P_k^s for each county in the area of interest being modeled.

Results

This section of the paper examines the estimation results for the regression model examining farmers' willingness to harvest corn stover; presentation of corn stover supply for Kansas; and related comparative statics.

Farmers Willingness to Harvest Corn Stover and Willingness-to-Pay for Contract Attributes

Table 1provides the estimation results for the conditional logistic regression model of farmers' willingness to harvest corn stover and select willingness-to-pay measures for different contract attributes. The McFadden Pseudo-R^2 value (0.53) indicates a relatively good fit for the model to the data. Two regional dummy variables (for the western and central regions) were included in the model to capture differences across regions. The western regional dummy variable was statistically significant indicating that farmers in western Kansas are less likely to harvest corn stover compared to farmers in northeastern Kansas. The error components were only significant for Option C. Inclusion of the error components allows for substitution between the options in estimated conditional logistic regression model estimated, by relaxing the independence of irrelevant alternatives assumption of the conditional logistic regression model. The results suggest that there is likely some heterogeneity may arise due to differences in survey respondents' preferences for different contract attributes. Not taking account of preference heterogeneity may bias model results.

All of the coefficient estimates on the contract attributes in Table 1 are statistically significant at a 1 percent level of significance. Coefficient estimates indicate that as net returns per acre under the contract increase the likelihood of producing corn stover will increase. Furthermore, as the length of a contract increases, the likelihood of harvesting corn stover decreases, indicating farmers find longer contracts undesirable, possibly due to reduced management flexibility for the farmer. Having a biorefinery harvest option increases the likelihood of producing corn stover, providing more flexibility for timing of farming operations. Nutrient replacement is a significant concern and the results indicate that farmers are more likely to harvest corn stover if the nutrients are replaced. Figure 2 provides a visual representation of farmers' willingness to harvest corn stover under different contract length options (2, 5, and 8 years). The probability curves illustrate how as contract length increases farmers' willingness to harvest corn stover decreases for all levels of net returns received under the contract.

The willingness-to-pay estimates provide what a farmer may be willing to give up or require in net returns for a marginal change in a contract attribute, depending on the favorability of the contract negotiated. Results in Table 1 show farmers' willingness to pay for different levels of certain contract attributes, which are statistically significant at the 1 percent level of significance. Longer contracts may provide less flexibility for farmers, especially in an uncertain market. Based on model results, farmers would be willing to pay or willing take a reduction in net returns equal to $1.60 per acre under contract to reduce the length of the contract by 1 year. The addition of a biorefinery harvest option can provide additional flexibility for the farmer, especially if the timing of practices for other cropping enterprises overlap or interfere. A farmer's willingness to pay to have this option in the contract is equal to $10.95 per acre. That is, this represents the amount a farmer would be willing to pay to have the option of the refinery or a custom harvester harvest and collect the biomass from the field. For the harvest of crop residues, farmers are willing to pay $11.03 per acre for a nutrient replacement option in a contract to harvest corn stover as a biofuel feedstock. While this amount may not reflect the actual loss in nutrients due to residue removal and potential soil loss, the amount indicates that farmers are aware of this loss and would like to have the option to be compensated for it when choosing a contract. The nutrient loss may lower yield potential of the crop planted after removal (Blanco-Canqui and Lal, 2009; Hess *et al*., 2009). More details on these results are available in Bergtold *et al*. (2014).

Corn Stover Supply

Figure 3 presents the corn stover supply curve at the farm level for Kansas, assuming farmers were offered a 2 year contract with both biorefinery harvest and nutrient replacement options. The break-even prices at $0 of net return ranged from $50.99 to $73.53 per dry ton based upon the quantity of corn stover biomass available for harvest and adoption rates. It should be emphasized that the supply curve estimate here is dependent upon the assumptions made and can be re-estimated for different situations (e.g. changes in harvesting costs, conservation practice adoption and requirements, etc.). Fitting the data in Figure 3 to a Cobb-Douglas function, gives an own-price supply elasticity for the state of Kansas (standard error) of 8.56 (0.30). The R^2 for the estimated fit was 0.94, indicating a relatively good fit to the data, providing support for this functional form assumption.

As mentioned earlier, the supply curve may shift if contract options change. Figure 4 provides an idea of the impact of increasing contract length from 2 to 5 years, which result in a decrease in supply. The increase in contract length will result in an increase in the transaction cost to the farmer under the contract. The farmer now has less flexibility in the future. In addition, the supply curve becomes more elastic, given the decrease in flexibility and increased transaction costs under the more stringent contract option. The own-price supply elasticity goes from 8.56 (2 year contract) to 10.41 (5 year contract), assuming a Cobb-Douglas functional form.

Spatial Variation in Supply

Solving the optimization problem given by equation (9) at an adoption level $\bar{Z} = 0.50$ can provide an idea of the spatial variation of the supply and prices that a biorefinery may face. Recall, the problem assumes a biorefinery or processor requires a certain percentage of adoption based on the potential supply in a geographical region (in this case, the state of Kansas). The optimal solution to the problem provides the level of net return the farmer would use, which can be translated into a price for the biomass that would be needed to obtain that level of adoption or willingness to harvest. For $\bar{Z} = 0.50$, the average net return required would be $24.57 per acre to achieve a 50% rate of harvest of potential corn stover. The amount of stover harevested spatially across the state by county is provided in Figure 5. and 6 provide a visual presentation of spatial variation in corn stover supply and price respectively, based on an optimization problem for finding the level of supply and returns needed to achieve 50% adoption statewide. The results show that the average statewide net return needed across counties to achieve this level of adoption was $24.57 per acre. Of interest, is that a good amount of stover would come from the Southwest corner of the state where an existing cellulosic biorefinery is currently under construction. Figure 6 provides the price per dry ton of corn stover that would be needed in each county to obtain the optimal level of net return or $24.57 per acre. Areas with less supply in Figure 5 have higher prices in Figure 6.

Conclusion

The paper examines supply potential of corn stover taking into account farmers' willingness to harvest corn stover under alternative contractual, pricing, and harvesting arrangements. The analyses include estimation of the probability of farmers' willingness to harvest corn stover under contract and the supply potential of corn stover in Kansas, as well as examining the impact of different contract and market attributes on adoption. The main results indicate that farmers are willing to harvest crop residues, such as corn stover, under contract. All the contract attributes examined were significant at the 1% level, indicating that farmers' willingness to supply corn stover will depend on contract alternatives and the net returns from the enterprise. To supply corn stover farmers will require an "adoption premium" that accounts fortheir risk premium, transaction costs, and uncertainty. Farmers' willingness-to-pay for an additional year of the contract, presence of a biorefinery harvest option, and a nutrient replacement provision were $1.55, $10.69 and $11.20, respectively. Model results also provide the ability to estimate probability curves at different levels of net returns and supply curves for corn stover at the farm level. For example, at a price of $53.50 ($73.90) farmers in KS are willing to supply 504,185 (8,139,190) dry tons of corn stover for biofuel production. The results from assessment of spatial variation indicate that different regions of Kansas (and surrounding regions) will give rise to different adoption patterns of harvesting corn stover as a biomass feedstock alternative.

These results have important implications for agribusinesses, the bioenergy industry and farmers to help establish needed contractual relationships to ensure a biomass feedstock supply or market development of cellulosic biofuels; identify potential areas to place a biorefinery; and provide a methodology for price discovery. Markets for cellulosic biomass intended for biofuel production either do not exist or are extremely limited in scope. The potential interest is significant, in that they will provide extra revenue stream for farmers who are more likely to produce biomass with some type of contractual agreement. Bio-refineries need an ensured supply of biomass to operate their plants and obtain financing. The combination of a unique data from stated choice survey in Kansas and flexible modeling approach in this study has a potential to make a valuable contribution to the literature and to stimulate interesting discussions among applied economist, policy makers, and industry players.

References

Anand, M. D.W. Archer, J.S. Bergtold and E. Canales. "Balancing Feedstock Economics and Ecosystem Services." In: *Sustainable Feedstocks for Advanced Biofuels: Sustainable Alternative Fuel Feedstock Opportunities Challenges and Roadmaps for six U.S. Regions*. R. Braun, D. Karlen and D. Johnson (eds.). Ankeny, IA: Soil Water Conservation Society, 2011.

Bergtold, J.S., J. Fewell and J. Williams. (2014). "Farmers' Willingness to Produce Alternative Cellulosic Biofuel Feedstocks Under Contract in Kansas Using Stated Choice Experiments." *Bioenergy Research*. DOI 10.1007/s12155-014-9425-9. Available at: http://link.springer.com/article/10.1007/s12155-014-9425-9#. Accessed 27 May 2014.

Bhat CR (1998) Accommodating flexible substitution patterns in multidimensional choice modeling: formulation and application to travel mode and departure time choice. Transp Res Part B 7: 455-466

Blanco-Canqui H, Lal R (2009) Crop residue removal impacts on soil productivity and environmental quality. Crit Rev Plant Sci 28: 139-163.

Cook RD, Nachtsheim CJ (1989) Computer-aided blocking of factorial and response-surface designs. *Technometrics* 31: 339 – 346

Fewell JE, Lynes MK, Williams JR, Bergtold JS (2013) Kansas farmers' interest and preferences for growing cellulosic bioenergy crops." J Amer Soc Farm Manag Rural Apprais 76**:**131 - 152

Gallagher, P.W. and H. Baumes. (2012). "Biomass Supply From Corn Residues: Estimates and Critical Review of Procedures." USDA, Office of the Chief Economist, Office of Energy Policy and New Uses, Agricultural Economic Report Number 847. Available at: http://www.usda.gov/oce/reports/energy/Biomass%20Supply%20From%20Corn%20Residues-Nov-2012.pdf. Accessed: 27 May 2014.

Gallagher, P., M. Dikeman, J. Fritz, E. Wailes, W. Gauthier, and H. Shapouri, "Supply and Social Cost Estimates for Biomass from Crop Residues in the United States," *Environmental and Resource Economics* 24 (April 2003):335-358.

Graham LR, Nelson R, Sheehan J, Perlack RD, and Wright LL (2007) Current and potential U.S. conr stover supplies. Agron J 99: 1-11

Greene WH (2007) NLOGIT Version 4.0: Reference Guide. Econometric Software, Inc, Plainview, NY

Greene WH (2012) Econometric analysis. 7th edn. Prentice Hall , Upper Saddle River, NJ

Hess RJ, Kenney KL, Wright CT, Perlack R, Turhollow A (2009) Corn stover availability for biomass conversion: situation analysis. Cellulose 16: 599-619.

KSU Research & Extension, Farm Services Agency. "Soil Management - Tillage Practice Data". 2010. Available at: http://www.agronomy.ksu.edu/extension/p.aspx?tabid=143

Larson JA, English BC, Lambert L (2007) Economic analysis of the conditions for which farmers will supply biomass feedstocks for energy production. Final Report for Agricultural Marketing Center Special Projects Grant 412-30-54, Agricultural Marketing Resource Center, University of Tennessee. http://www.agmrc.org/media/cms/2007UTennProjDeliverable_9BDDFC4C2F4E5.pdf. Accessed 30 August 2012

Louviere JJ, Hensher DA, Swait JD (2000) Stated choice methods: analysis and application. Cambridge University Press, Cambridge, UK

National Agricultural Statistics Service (NASS) (2007) 2007 Census Publication. USDA. Available at: http://www.agcensus.usda.gov/Publications/2007/index.php Accessed 3 February 2009

National Agricultural Statistics Service (NASS) (2012) Quickstats 2.0. Available at: http://nass.usda.gov/Quick_Stats/. Accessed 1 August 2014.

Nelson R, Langemeier M, Williams j, Rice C, Staggenborg S, Pfomm P, Rogers D, Wang D, Nippert J (2010) Kansas biomass resource assessment: assessment and supply of select biomass-based resources. Research report prepared for the Kansas Bioscience Authority, Olathe, KS

Nguyen N, Miller AJ (1992) A review of some exchange algorithms for constructing discrete D-optimal designs. Comput Stat Data Anal 14: 489 – 498

Perlack RD., Wright LL, Turhollow AF, Graham RL, Stokes BJ, Erbach DC (2005) Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply. U.S. Department of Agriculture and U.S. Department of Energy, Washington, DC

Roe B, Sporleder TL, Belleville B (2004) Hog producer preferences for marketing contract attributes. Am J of Agric Econ 86: 115 – 123

Shearer, D. (2014). Optimization of Cellulosic Biomass Analysis. MS Thesis, Department of Agricultural Economics, Kansas State University. Available at: http://krex.k-state.edu/dspace/bitstream/handle/2097/16995/DustinShearer2014.pdf?sequence=6. Accessed 27 May 2014.

Walsh ME, de la Torre Ugarte DG, Shapouri H, Slinsky SP (2003) Bioenergy crop production in the United States. Environ and Resource Econ 24: 313 -333

Table 1: Conditional Error Component Logistic Regression Results for Corn Stover

Variable (Attribute)[c]	Corn Stover Coefficient Estimate (Standard Error)[a]	Willingness-to-Pay[b]
Intercept	-4.49** (0.62)	---
Net Returns	0.13** (0.0084)	---
Contract Length	-0.21** (0.029)	-$1.60** (0.20)
Biorefinery Harvest Option	0.73** (0.075)	$10.95** (1.09)
Insurance Availability	---	---
Nutrient Replacement	0.74** (0.067)	$11.03** (1.16)
Government Incentive Payment	---	---
Seed/Est-ablishment Cost Share	---	---
Western, KS	-1.26* (0.76)	---
Central, KS	0.99 (0.70)	---
	Error Components	
Contract A	0.32 (14.96)	
Contract B	0.49 (17.87)	
Option C (Do Not Adopt)	3.58* (2.01)	
	Fit Statistics	
Log-Likelihood	-738.85	
McFadden Pseudo R^2	0.53	
AIC	1.05	
Number of Observations[d]	1420	

[a] * indicates statistical significance at the 0.10 level, and ** indicates statistical significance at the 0.01 level.

[b] Willingness-to-Pay for an attribute is calculated as the attribute coefficient divided by the *net returns* attribute coefficient following Greene (2012). Asymptotic standard errors were estimated using the delta method (Greene, 2012).

[c] All binary attributes are all effects coded for model estimation.

[d] The number of observation is equal to the number of usable surveys times 5, given each respondent answered 5 choice questions for each stated choice experiment conducted.

Corn Stover Scenario:

		Contract A	Contract B	Option C
Contract Features	**Net Returns**	$0/acre/year	$30/acre/year	Do Not Adopt
	Contract Length	2 years	2 years	
	Biorefinery Harvest	Yes	No	
	Nutrient Replacement	No	Yes	
	Your Ranking (1-3)	2003	2004	2005

Figure 1: Example Choice Scenarios/Questions for Stated Choice Experiment

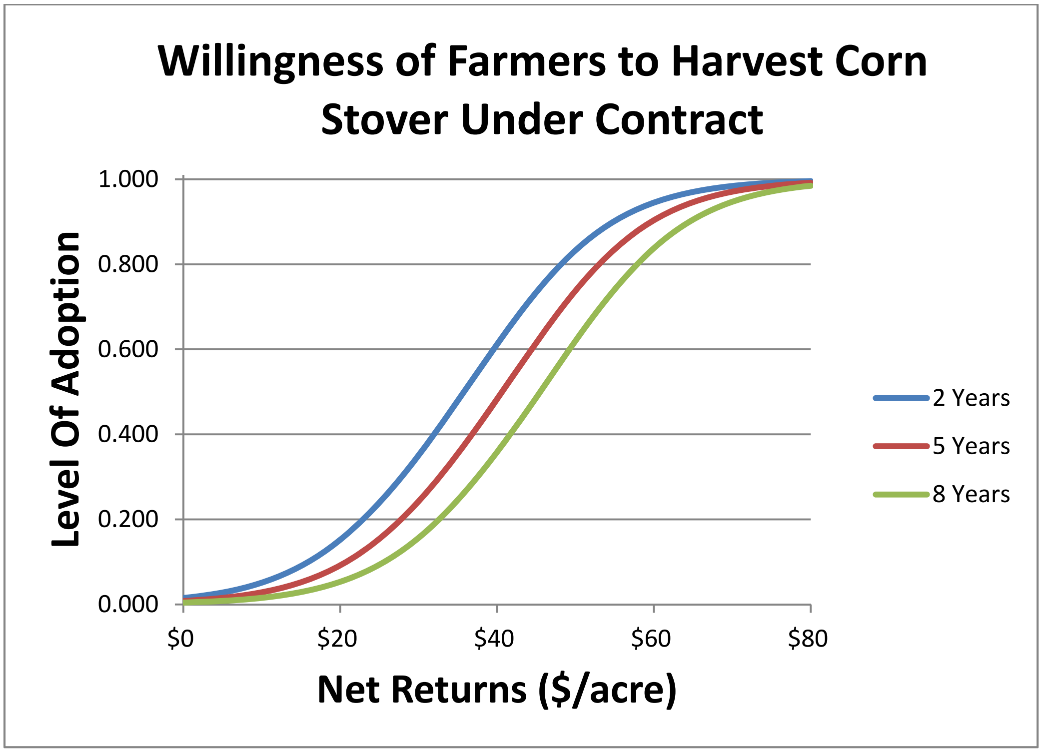


Figure 2: Probability of Harvesting Corn Stover Under Contract for Different Contract Lengths

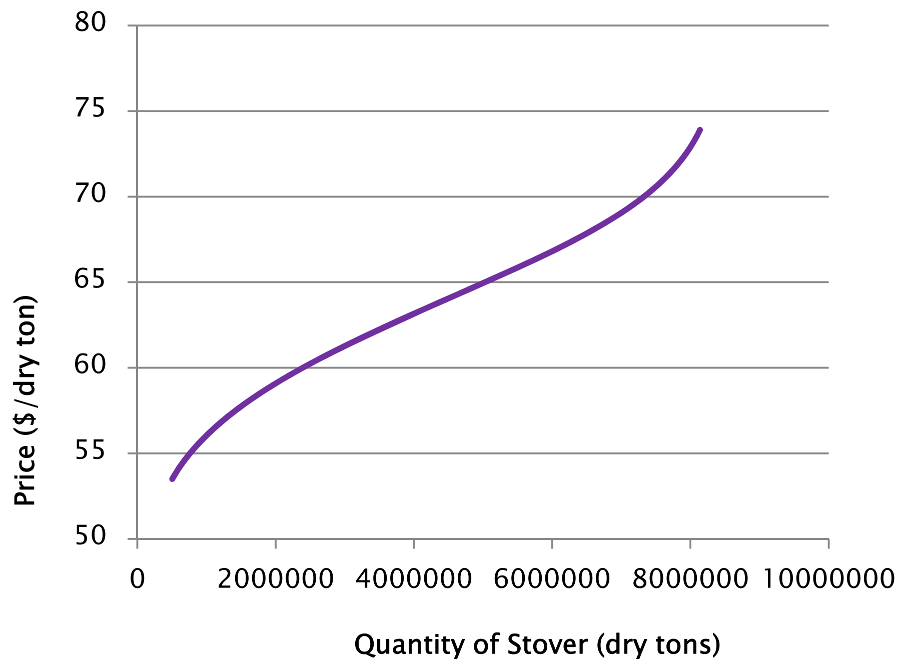


Figure 3: Initial Supply of Corn Stover in Kansas

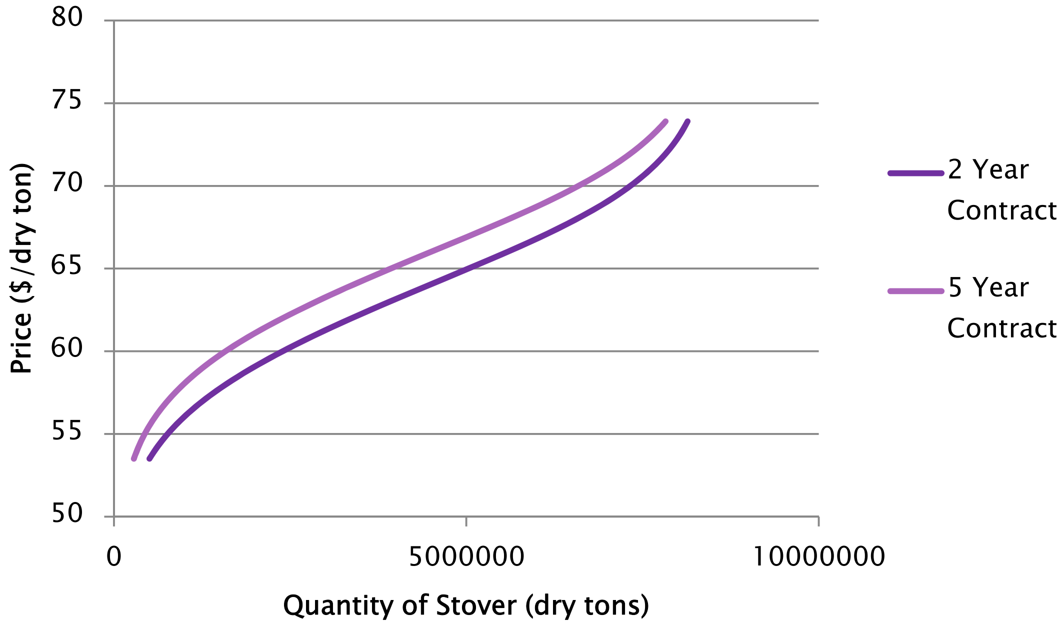
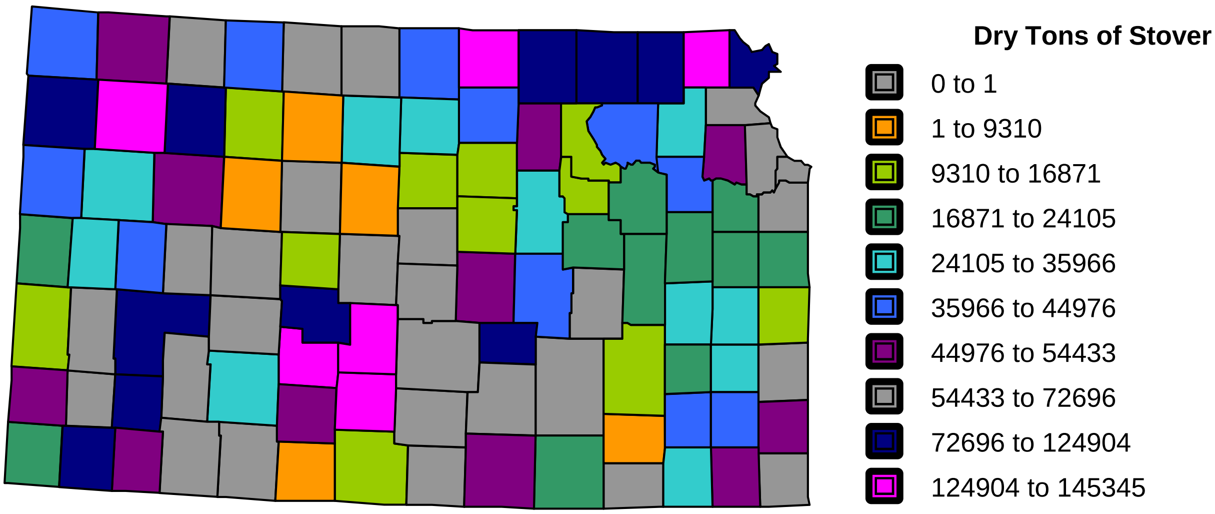
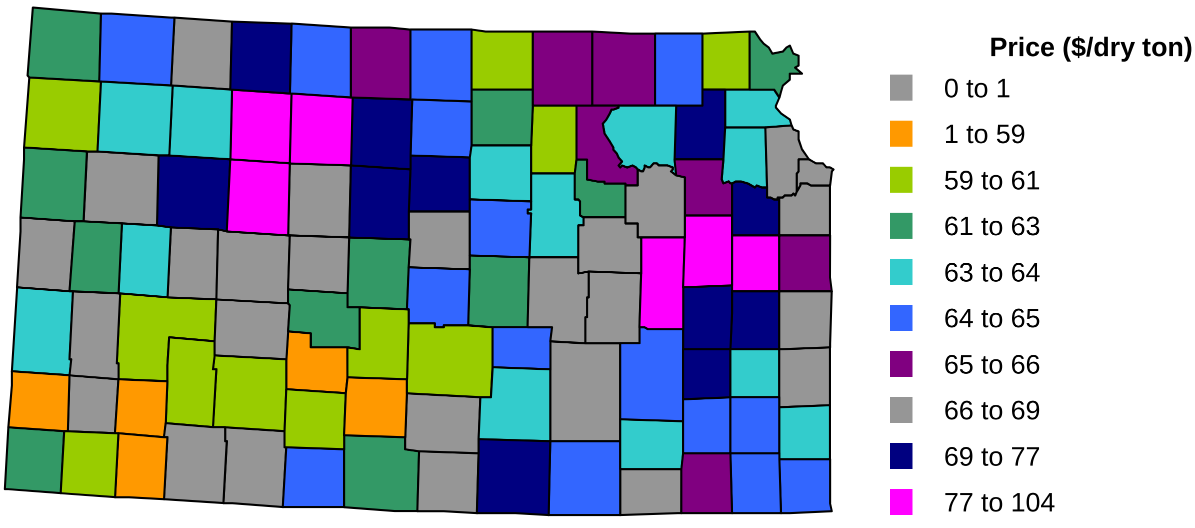


Figure 4: Shift in Supply of Corn Stover with Increase in Contract Length



Note: Counties with 0 values may either have no supply or data was not directly provided by USDA-NASS for that county.

Figure 5: Spatial Variation in Corn Stover Supply



Note: Counties with 0 values may either have no supply or data was not directly provided by USDA-NASS for that county.

Figure 6: Spatial Variation in Corn Stover Price