The Impacts of the Canadian Wheat Board Ruling on the North American Malt Barley Markets: Demonstrating a Copula Approach to Data Simulation

Heidi Schweizer, M.S., Montana State University, Bozeman, MT

ABSTRACT

The 2011 Marketing Freedom for Grain Farmers Act deregulated Canadian grain markets and removed the Canadian Wheat Board as the sole buyer and seller of Canadian grain. We present a rational expectations contract decision model that serves as the basis for an empirically informed simulation analysis of malt barley contracting opportunities between Canadian farmers and U.S. brewers in the deregulated environment. This analysis is accomplished by using a copula approach and in this paper we demonstrate how the experimental COPULA procedure was applied in this context. The copula approach allows us to simulate data specifying the dependence structure and the marginal distributions of the simulated variables separately. This mechanism allows us to avoid making strong assumptions about the joint distributions of price and yield variables and also allows us to avoid unrealistic outcomes when simulating data. With this methodology we are able to make predictions about the likelihood of favorable conditions for contracts between Canadian farmers and U.S. brewers in deregulated Canadian grain markets. Our results indicate that new opportunities for contracting are possible, but the likelihood of favorable conditions for U.S. brewers to contract with Canadian rather than U.S. farmers is low–between 2% and 35%.

INTRODUCTION

Over the past decade, copulas have gained popularity as an essential modeling tool within finance. Broadly, copulas are functions that can be used to simulate a dependence structure independently from the marginal distributions. They are useful in simulation models because, when there is more than one random variable of interest, for example risk factors and volatilities of stocks, it is necessary to specify the marginal distributions which may be straightforward. However, the joint distribution must also be fully specified, though the joint relationship may be not be straightforward. But when simulating each variable separately without specifying the joint distribution, one makes the assumption that the variables are independent. The copula approach provides a way to avoid this assumption (Greene 2011).

Applications of copulas in finance include asset pricing, risk management, and credit risk analysis (Cherubini, Luciano, and Vecchiato 2004). One specific application of copulas has been to measure the risk of holding financial assets, and it is because of this use that copulas have become infamous due to their perceived role in the 2008 financial crash (Lee 2009). While copulas are best known for their use within a financial context, they can be a useful tool within other fields. For example, Cameron et al. (2004) applied a copula within health. They used a bivariate copula approach to analyze Australian data on self-reported and actual physician visits to determine health care demand in Australia. This paper demonstrates how copulas can be applied within economics to agricultural markets by using the experimental SAS COPULA procedure.

THE CANADIAN WHEAT BOARD AND MALT BARLEY MARKETS

Until August 2012, the Canadian Wheat Board was, by law, the sole buyer and seller of grain grown in the Great Plains Provinces of Alberta, Saskatchewan, and Manitoba. However, the *Marketing Freedom for Grain Farmers Act (2011)* changed the law so that Great Plains farmers may now sell their grain on the free market. This results in new possibilities for both Canadian malt barley farmers and U.S. brewers seeking to procure malt barley. Malting barley, used in making beer, is usually sold under contract and it is conceivable that U.S. brewers might now choose to contract with Canadian farmers instead of U.S. farmers.

Because the provisions of the *Marketing Freedom for Grain Farmers Act (2011)* were implemented in August 2012 it is currently infeasible to directly measure the effects on contracting between U.S. brewers and Great Plains Farmers for the production and delivery of malting barley resulting from the end of the Canadian Wheat Board's monopoly and monopsony. However, historical yield, price, and transaction cost information used in conjunction with a theoretical model of farm and firm decision making can be used to simulate likely market conditions and provide insight into the likelihood of contracting between the two parties. The analysis focuses on identifying incentives for such contracting in the major barley growing regions of Canada and the United States, these are the Great Plains Provinces and the U.S. states – Idaho, Montana, and North Dakota.

In order for contracting to occur between the two parties we evaluate a farmer's expected benefits from growing malt barley instead of spring wheat using a constant relative risk aversion expected utility framework

$$\lambda \frac{(\hat{P}_m \hat{y}_b)^{1-r}}{1-r} + (1-\lambda) \frac{(\hat{P}_f \hat{y}_b)^{1-r}}{1-r} \geq \lambda \frac{(\hat{P}_w \hat{y}_w)^{1-r}}{1-r}, \tag{1}$$

and the costs for a brewer to source malt barley in Canada versus the United States

$$P_m \leq \hat{P}_m^{U.S.} + \left[(\hat{t}^{U.S.} \hat{d}^{U.S.}) - (\hat{t}_1^{Can} \hat{d}_1^{Can} + \hat{t}_2^{Can} \hat{d}_2^{Can}) \right]. \tag{2}$$

Where for price and yield variables in either condition, x, $\hat{x}$ represents a simulated value; P_m and $P_m^{U.S.}$ denotes Canadian and U.S. malt barley prices, P_w and P_f are Canadian feed barley and spring wheat prices, y_b and y_w barley and spring wheat yields. $\hat{t}^k$ is the simulated rail rate in country k; $\hat{d}^k$ is the estimated rail mileage traveled in country k (and invariant across simulated draws). Lastly, r represents farmer risk aversion preferences and λ represents the malt barley selection rate – the percentage of malt barley that meets malt quality standards.

The empirical model relies on simulating wheat and barley yields and simulating wheat, barley, and rail transportation prices. In addition to determining historical marginal distributions, it is also important to consider the potential for correlations among yields and prices within and across regions. Such correlations may occur because nearby regions are similarly affected by weather conditions (Xu et al. 2010), large price differences are relatively quickly arbitraged away, and prices and yields are inversely related (Vedenov 2008). Figure 1 provides visual evidence of a relationship between the two yield variables by showing historical values of Alberta spring wheat and barley yields. Correlations tests across yields and prices indicate the potential for three types of dependencies: within a location across barley and spring wheat yields and prices; between locations and across barley and spring wheat yields; and between locations and across yields of a particular crop. Although there was no statistical evidence of dependence among spring wheat yields and prices and among barley yields and prices, there was correlation between and across the yield variables and between and across the price variables.[1]

COPULA FUNCTION

To account for these relationships and simulate values for the joint multivariate distributions of yields and prices we apply a copula function which provides a flexible approach to accommodate high dimensional correlation structures among stochastic variables. Specifically, joint distributions can be characterized as the product of independent marginal probability densities and a unique copula function (Greene 2011).

For example, the joint yield distribution for wheat and barley yields within a location, say Alberta, can be characterized as:

$$F_{wheat,\ barley}(yield_{wheat}, yield_{barley}|\bullet) = C[F_{wheat}(yield_{wheat}|\bullet), F_{barley}(yield_{barley}|\bullet), \beta],$$

where the marginal cdfs of two random variables are fully specified as $F_{wheat}(yield_{wheat}|\bullet)$ and $F_{barley}(yield_{barley}|\bullet)$, data and parameters are denoted $\bullet$, the bivariate cdf is $F_{wheat,\ barley}(yield_{wheat}, yield_{barley}|\bullet)$, and β is a dependence parameter.

PREPARING FOR SIMULATION

To prepare for simulation with a copula, we first estimate the marginal distributions of the wheat and barley yields in each location, $F_i(yield_i|\bullet)$ for all i, and their correlation structure, β, using historical data.

The CAPABILITY proceedure was used to determine the marginal distributions of the variables. In the case of crop yields it is important to test whether historical yields in each region are more adequately characterized by a beta or normal distribution. The following code was used to determine the distribution for Alberta wheat yields. The θ and σ parameters specified when fitting the beta distribution are simply the lower bound, θ, and the upper bound, $\theta + \sigma$, of the historical data.

[1] For a more in depth discussion of the institutional change in Canada, how the theoretical model was developed, the data, and the simulation results, see Bekkerman, Schweizer, and Smith (2013).

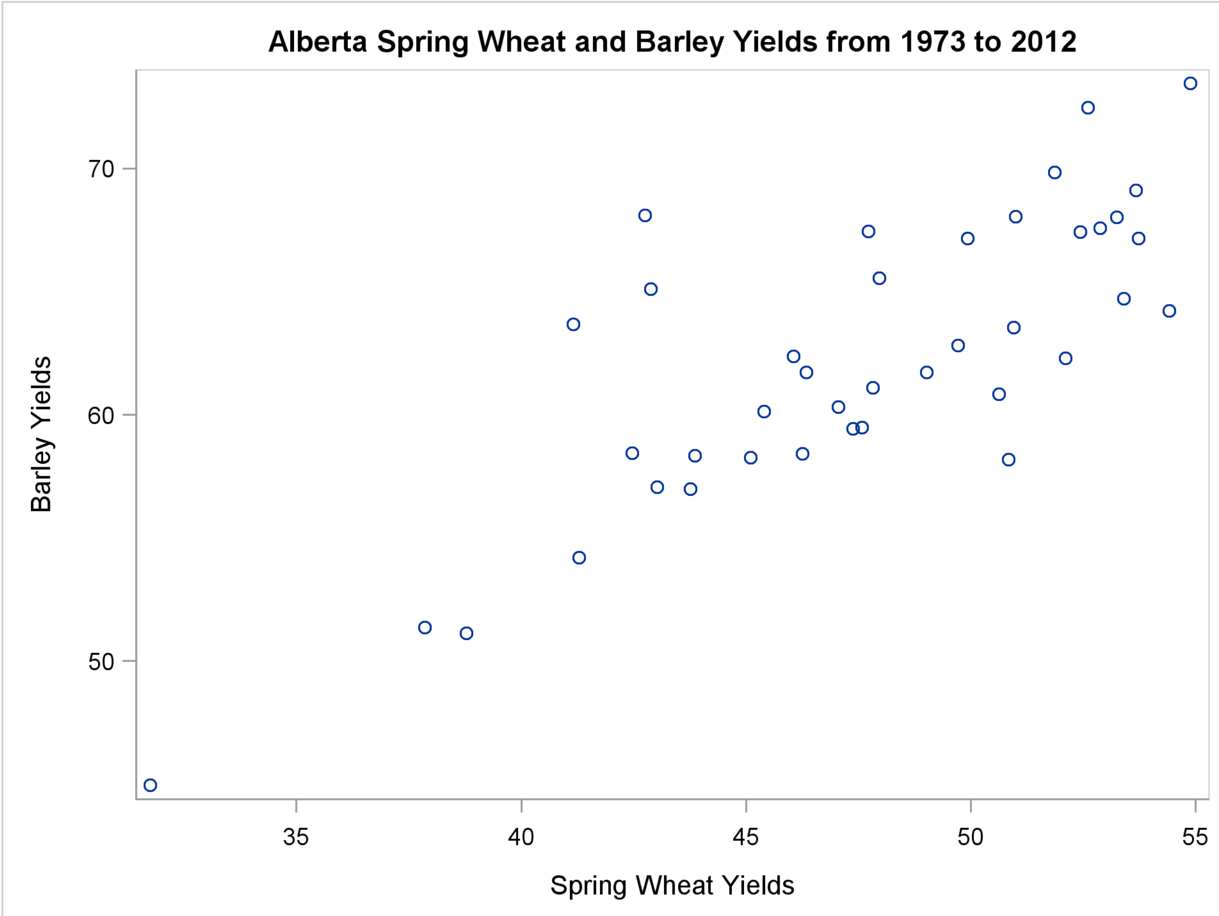

Figure 1: Yields are in bushels per acre. Spring wheat and barley yields are in units of "2012 yields" in order to account for yield trends acrross time due to advances in farming technology. These data were obtained from the Canada Grains Council.

```
proc capability data = yields;
title 'Fitted BETA distribution';
/* Plot histogram; overlay with beta distribution */
histogram /
beta (theta=44.5 sigma=29) ;
/* Inset, showing various statistics */
inset mean max min skewness var BETA (chisq pchisq ad adpval cvm cvmpval ksd ksdpval);
/* Tells SAS which variable to use */
var alberta_barley_yield;
run;

proc capability data = yields;
title 'Fitted NORMAL distribution';
/* Plot histogram; overlay with normal distribution */
histogram /
normal;
/* Inset, showing various statistics */
inset mean max min skewness var normal (chisq pchisq ad adpval cvm cvmpval ksd ksdpval);
/* Tells SAS which variable to use */
var alberta_barley_yield;
run;
```

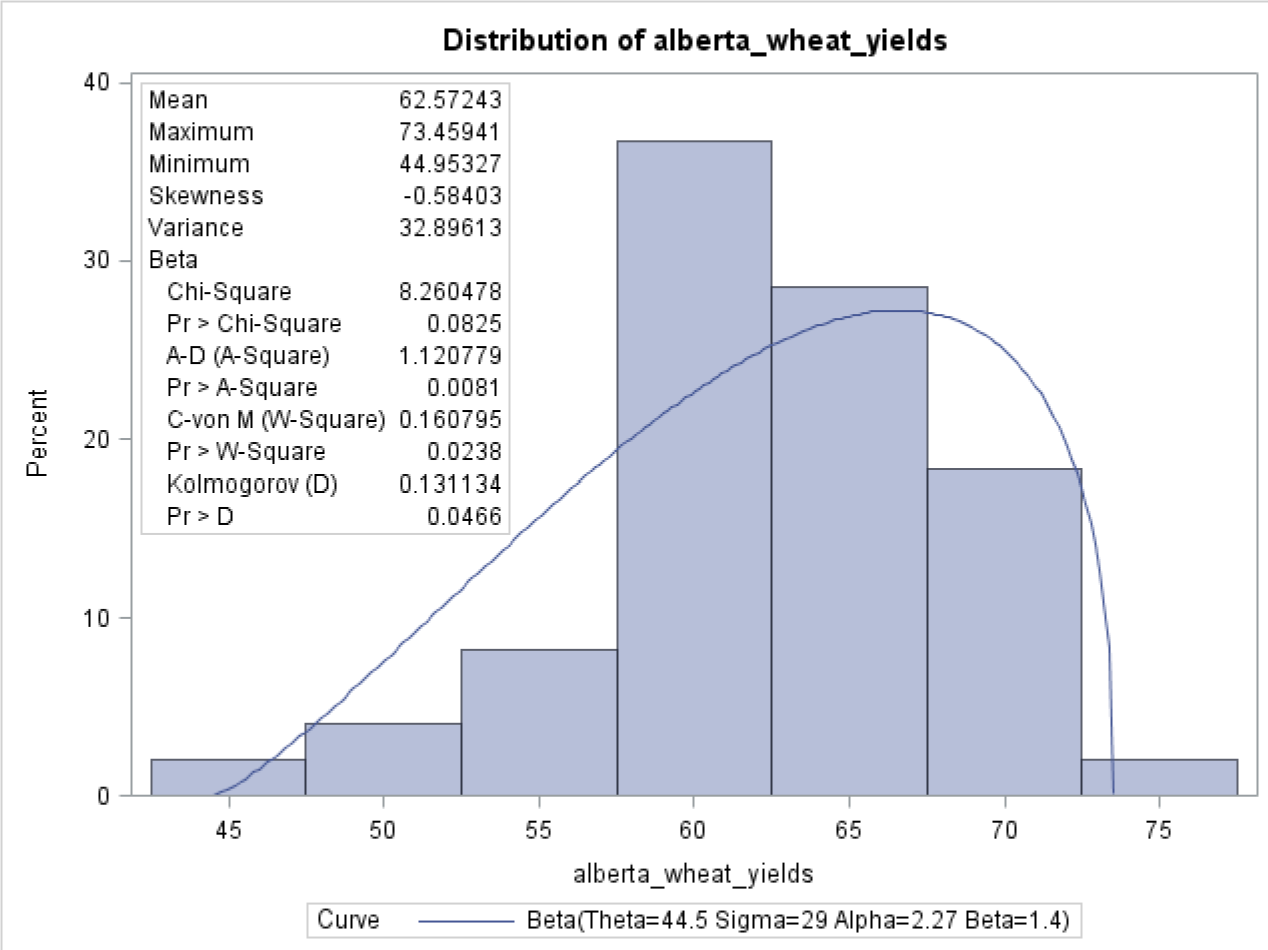

Figure 2: Fitted beta distribution of Alberta wheat yields.

Figures 2 shows the fitted beta distribution of Alberta wheat yields output by PROC CAPABILITY. Inset in the histogram are the results from the distributional tests and their *p*-values. Below the histogram are the estimated distribution parameters. The same information is generated when fitting a normal distribution and can be used to determine the correct distribution and distributional parameters to use for simulation.

After determining the marginal distributions and distributional specifications for each variable that will be simulated, the CORR procedure is used to estimate the covariance structure between the yield variables.[2] PROC CORR allows us to determine the dependence structure, β, between, for example, Alberta wheat and barley yields, and wheat and barley yields in the other Great Plains Provinces and U.S. malt barley growing regions. Here we are estimating the covariance between spring wheat and barley yields within Alberta.

```
proc corr data = yields
/*specify the type of correlation*/
spearman
noprint
/*keep just the correlation estimates*/
outs = estimates(where = (_TYPE_ = "CORR")
keep =  _TYPE_ alberta_wheat_yield alberta_barley_yield );
var alberta_wheat_yield alberta_barley_yield;
```

[2]PROC COPULA can also be used to find the correlation structure.

```
run;

/*keep just the correlation estimates*/
data estimates; set estimates;
drop _TYPE_;
run;
```

SIMULATION

Next we used PROC COPULA to simulate the multivariate distributions of yields and prices based on the correlation estimates found by PROC CORR, using the Gaussian Copula. The following code results in a data set, “simulated_uniforms”, which is a set of 1000 observations of values between 0 and 1 that have the correlation structure corresponding to spring wheat yields and barley yields in Alberta.

```
/* Use the empirical correlation estimates, in the data set "estimates," to draw values
from a normal copula function */
proc copula;
   var  alberta_wheat_yield  alberta_barley_yield;
   define  cop normal (cor = estimates);
   simulate cop / ndraws     = 1000
                  outuniform = simulated_uniforms
                  plots = (data = uniform scatter);
run;
```

The last step of the simulation is transforming the simulated values to the correct marginal distributions, the beta distribution, using the distributional specifications of the historical data previously found using PROC CAPABILITY.

```
/* set the beta distribution values determined by using proc capability */
\%let wheat_min = 31;
\%let wheat_max = 55;
\%let wheat_alpha = 2.227;
\%let wheat_beta = 1.4;

\%let barley_min = 44;
\%let barley_max = 74;
\%let barley_alpha = 2.867;
\%let barley_beta = 1.809;

/* transform the simulated values the beta distribution */
data beta ; set simulated_uniforms;
wheat_yields = &wheat_min
+quantile('BETA',wheat_yields,&wheat_alpha,&wheat_beta)*(&wheat_max - &wheat_min);
barley_yields = &barley_min
+quantile('BETA',barley_yields,&barley_alpha,&barley_beta)*(&barley_max - &barley_min);
run;
```

The variables simulated in this example are shown in Figure 3. In the context of our analysis of the North American malt barley markets we used this process for all the yield and price variables for each region in order to obtain the information to determine whether the contracting conditions specified by equations (1) and (2) are satisfied. By evaluating the contracting conditions we were able to determine whether or not malt barley contracting would occur between a Great Plains farmer and a U.S. brewer for each observation.

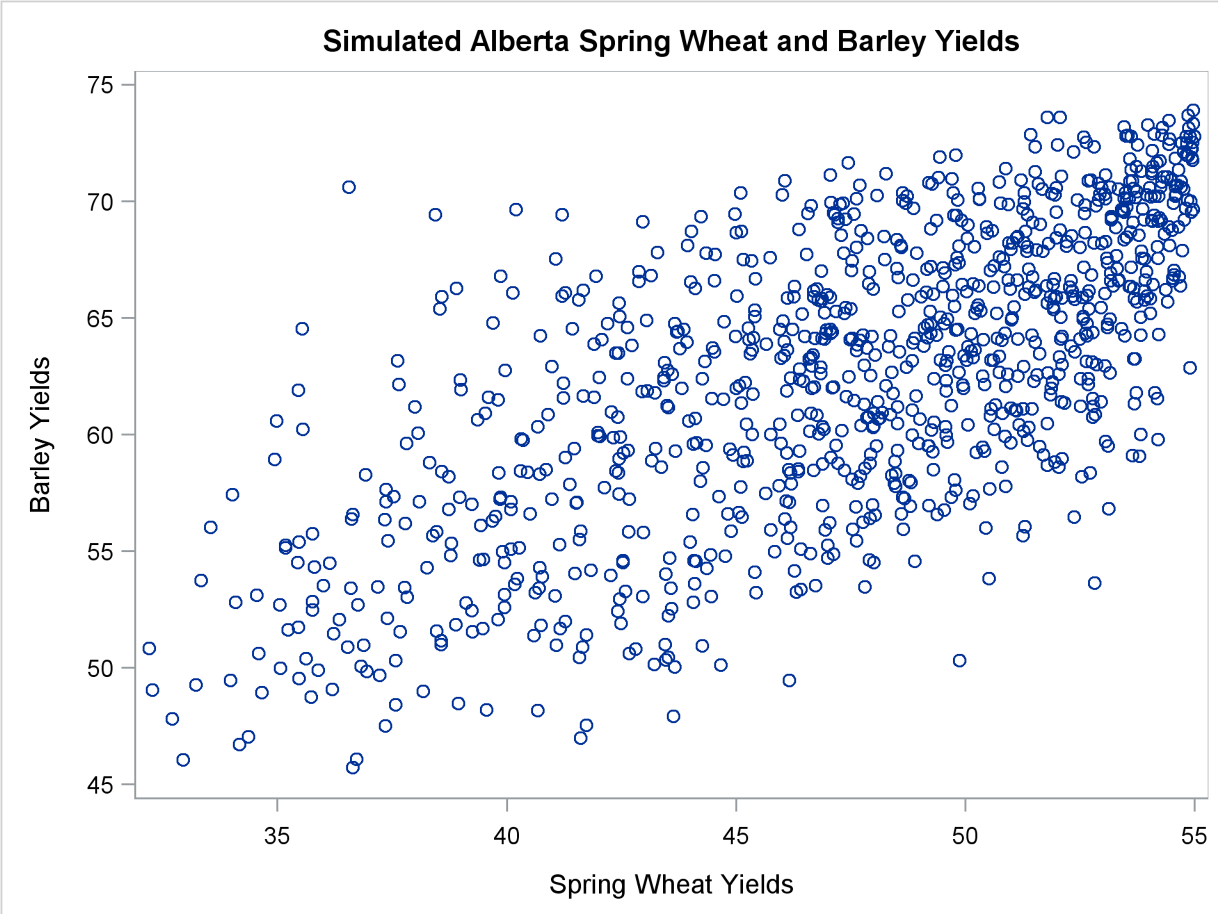

Figure 3: Yields are in bushels per acre.

RESULTS

This simulation offers important insights about the future North American malt barley markets and how legislative changes in Canada may affect market participants. Using a Monte Carlo simulation in which draws are made from a copula function, we estimate the frequency with which Canadian farmers and U.S. brewers will have incentives to contract for malt barley in the absence of a Canadian Wheat Board with monopoly and monopsony powers. We find that Canadian Great Plains farmers may face new opportunities for marketing grains. However, the results of the simulation analysis indicate that market conditions suitable for contracting for malt barley production and delivery between Canadian Great Plains farmers and U.S. brewers occur relatively infrequently.

The likelihood that market conditions will be favorable to contracting with a U.S. brewer located in St. Louis, MO (the location of the Anheuser-Busch brewing headquarters) ranges from 23% to 35% in Manitoba and but can decrease to 4% at lower malt barley selection rates when farmers are highly risk averse. In Saskatchewan risk conditions are favorable 20% to 32% of the time but can decrease to 5% when farmers are highly risk averse. The likelihood that contracting will occur in Alberta ranges from 9% to 15% when farmers are risk neutral but can decrease to 2% due to farmer risk aversion preferences, the likelihood of favorable contracting conditions in Alberta are low because farmers in Alberta are relatively far from the U.S. companies' delivery points compared to farmers in the major U.S. barley production regions of Idaho, Montana, and North Dakota. Figure 4 presents the likelihood that contracting between a U.S. brewer located in St. Louis, MO and Alberta farmers would occur, given a farmer's risk aversion preferences and the selection rate of malt barley.

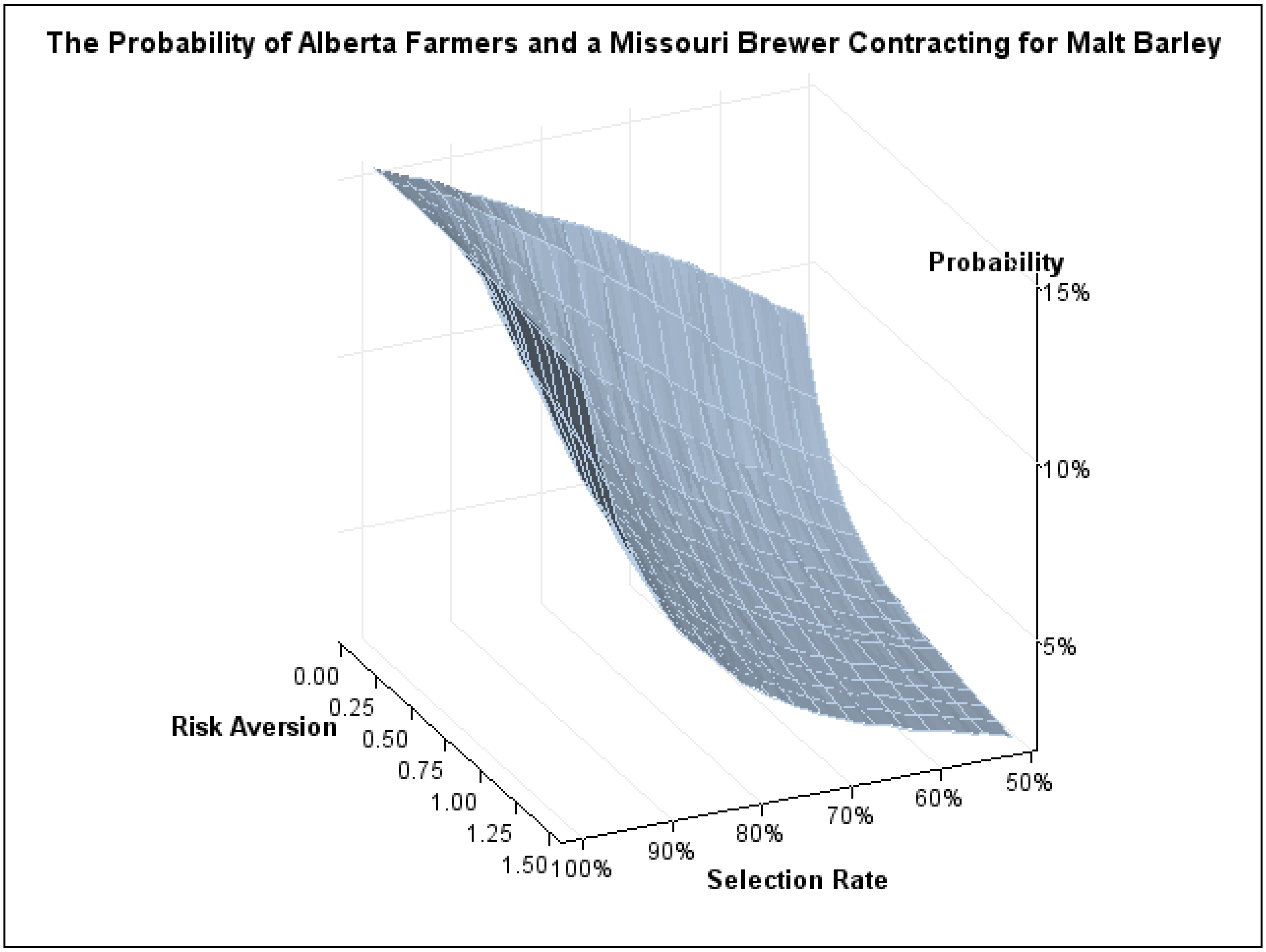

Figure 4: The malt barley selection rate refers to the percentage of malt barley that is of malt quality and accepted by U.S. brewers. The risk aversion parameter is the risk aversion coefficient within a constant relative risk aversion (CRRA) model. For more information about these results see Bekkerman, Schweizer, and Smith (2013).

CONCLUSION

Copulas can be useful outside of finance. A copula may be applied in a situation where one is simulating variables that might be related. In this example we applied a copula to agricultural markets. By using a copula in our simulation of spring wheat and barley yields, and spring wheat, barley, and rail prices we account for the relationships among the variables between and across malt barley growing regions. If we simulated each variable independently the resulting data set could include observations where, say within Alberta, spring wheat yields reflect a very rainy year but barley yields reflect a dry year. Drawing simulated values from a copula function results in more realistic observations.

Although it is still experimental, PROC COPULA provides a straightforward method of accounting for relationships among simulated variables. It is also possible to simulate using a copula with PROC MODEL (Erdman and Sinko 2008) and PROC IML. However, PROC COPULA is designed specifically for these types of simulations.

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ACKNOWLEDGMENTS

I would like to thank my M.S. thesis advisers Anton Bekkerman and Vincent Smith at Montana State University for their valuable modeling and programming insights.

CONTACT INFORMATION

Please address comments and questions to:

Heidi Schweizer
2116 Social Sciences & Humanities
University of California, Davis
One Shields Avenue
Davis, CA 95616
Phone: (760) 484-2890
schweizer@primal.ucdavis.edu