THE IMPACTS OF THE CANADIAN WHEAT BOARD RULING ON THE NORTH AMERICAN MALT BARLEY MARKETS

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The 2011 *Marketing Freedom for Grain Farmers Act* deregulated Canadian grain markets and removed the Canadian Wheat Board (CWB) as the sole buyer and seller of Canadian grain. We develop 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. maltsters in the deregulated environment. Comparative statics and simulation results indicate that some new opportunities for contracting are possible, but the likelihood of favorable conditions for U.S. maltsters to contract with Canadian rather than U.S. farmers is low—between 6% and 33% over a range of possible selection rates. The effects on contracting of the termination of the Canadian grain transportation revenue cap policy and of the relaxation of criteria for the release of new spring wheat varieties are also investigated. While changes to grain transportation policies are not likely to significantly affect favorable conditions for contracting, reducing constraints on Canadian farmers' access higher yielding wheat varieties could increase the returns from growing spring wheat but decrease the likelihood of contracting for malt barley with U.S. maltsters by an average of 5.5 percentage points.

Keywords: Canadian Wheat Board, contracting decisions, malt barley, rail rates, varietal control

JEL Codes: Q18, Q13, Q17, L14, D47

1. Introduction

Government policies, agencies and regulations have shaped many national food and agricultural systems and have had important impacts on international markets. In the Canadian Great Plains Provinces, the Canadian Wheat Board (a Crown Corporation) has had a major effect on the structure of agriculture for over 70 years through the use of its single-desk monopsony and monopoly powers to purchase and market malting barley and wheat for human consumption and export. The Canadian Wheat Board's (CWB's) single-desk authority has constrained farmers' marketing opportunities, affected prices through price pooling, has limited varietal choice, and had important impacts on crop mix and production decisions. The CWB's single-desk authorities, policies and day-to-day operations also had substantial impacts on the structure of the Canadian grain acquisition, transportation, and processing industries and affected international trade and trade relations, perhaps especially between Canada and the United States. In November 2011, the Canadian government decided to terminate the CWB's single-desk authority, allowing farmers to market their own wheat and malting barley. This decision is likely to have important short- and long-term economic effects on the production, marketing, and export of grain and oilseed in the Great Plains Provinces.

Previous studies of government sanctioned state trading enterprises (STEs) such as the CWB have mainly focused on modeling and quantifying the welfare effects and other potential distortions in trade and the efficiency of marketing services, market power, and food security. These studies generally find that STEs adversely affect economic efficiency and standard measures of economic welfare (for example, see

Veeman 1987; Alston, Carter, and Smith 1993; Carter, Loyns, and Berwald 1998; Alston and Gray 2000; Carter and Smith 2001; and McCorriston and MacLaren 2006). The impacts of disestablishing government-sanctioned STEs and expanded options for the use of alternative marketing channels on contracting decisions by market participants have not, however, been extensively studied.

This study investigates the effects of the 2011 *Marketing Freedom for Grain Farmers Act*, which deregulated the marketing and procurement of Canadian malt barley and altered the incentives for contracting between Canadian farmers and U.S. brewers for the production and delivery of malting barley. The new legislation enabled malt barley consumers, primarily large beer brewers in Canada and the United States, to contract directly for malting barley with farmers in Alberta, Manitoba, and Saskatchewan. By not having to work with or through the CWB, the opportunity costs for U.S. brewers and Canadian farmers to contract for malting barley have been reduced. We analyze the potential for malt barley contracting between Canadian barley producers and U.S. malting and brewing companies (maltsters) in the absence of a CWB with single-desk authorities.

The analysis addresses three important questions. First, how does the termination of the CWB's single-desk authority affect a Canadian farmer's contracting decisions? Second, what are the effects on U.S. maltsters' decisions to contract with Canadian or U.S. barley producers? Third, what market conditions are necessary to create incentives for Canadian farmers to establish contracts with two major U.S. malt barley procurers, MillerCoors, LLC and Anheuser-Busch Companies, LLC?[1]

We develop a formal rational expectations contract decision model that serves as the basis for an empirically informed simulation analysis of the feasibility of contracting for malt barley between Canadian farmers and U.S. maltsters in the deregulated environment. The simulation model is calibrated using historical Canadian and U.S. crop yield, price, and transportation cost data and used to consider a wide range of alternative assumptions about farmers' and maltsters' *ex ante* expectations of important variables. These include selection rates (the frequency with which malting barley crops will meet contract specific malting standards), malt barley yields and malt and feed barley prices, yields and prices for spring wheat (assumed to be the competing crop), and transportation costs. To ensure that the simulation analysis reflects historical relationships between spatial and cross-commodity yields and prices, we estimate empirical correlations among the price and yield variables and specify a copula function to simulate from a multivariate probability distribution.

The base case simulation assumes that while Canadian grain producers form expectations based on historical barley and wheat price distributions, the CWB's single-desk authority no longer constrains their opportunities to contract with U.S. maltsters. We also use the simulation model to investigate the impacts of other potential policy changes, including the termination of the rail transportation revenue caps imposed by the 1996 *Canadian Transportation Act* and the relaxation of criteria used in determining

[1] MillerCoors and Anheuser-Busch account for 70% of U.S. beer production.

whether new crop varieties should be released such as kernel visual distinguishability (KVD) as historically applied to spring wheat. This criterion was originally advocated by the CWB to create a unique brand for Canadian wheat exports, but may continue to be applied by the Canadian Grains Commission (CGC). The KVD and other CGC criteria have likely adversely affected spring wheat yields in the Great Plains Provinces by constraining Canadian Great Plains farmers' access to higher yielding varieties of wheat (Ulrich, Furtan, and Schmitz, 1987).

Empirical results indicate that some malt barley contracting opportunities would exist for farmers in all three Great Plains Provinces under a deregulated marketing structure, indicating that the CWB limited profit maximizing opportunities in North American grain markets. Generally, contracting with U.S. maltsters is most likely to take place in Manitoba, followed by Saskatchewan and Alberta. The major factors affecting contracting conditions are *ex ante* expectations about barley selection rates, spring wheat yields, and transportation costs. Higher expected selection rates raise the opportunity costs of producing competing crops and increase Canadian farmers' incentives to contract for barley production, while higher spring wheat yields increase their opportunity costs of producing malt barley. Increases in Canadian rail freight rates for grain lower U.S. maltsters' contracting incentives. For example, we show that relative to farmers in Alberta, producers in Saskatchewan and Manitoba are expected to be 4–18 percentage points more likely to contract because they are located geographically closer to the U.S. brewers.

The results also indicate that higher Canadian grain freight rates, associated with freight rate deregulation, may only have minimal effects on contracting incentives because the distance from Canadian farms producing malt barley to the U.S.–Canadian border is small relative to the distance from the border to the plants at which U.S. maltsters would take delivery of the grain. In contrast, relaxing controls over the release of new spring wheat varieties, which could result the adoption of higher yielding varieties currently grown in the United States, would reduce the probability that Canadian farms would contract with U.S. maltsters by as much as 11 percentage points. These results provide new insights about the complex relationships between government policies and agricultural market outcomes, especially when those policies restrict marketing opportunities and constrain production management decisions.

2. The Changing Policy Environment

The Canadian Wheat Board was permanently established in 1935 and given the authority in the 1940s to be a single-desk purchaser and marketer of malt barley and wheat from the Great Plains Provinces, both for domestic human consumption and for all exports of malting barley and wheat. In November 2011, the Conservative Party of Canada, whose platform partly focused on market deregulation, succeeded in obtaining legislation to end the CWB's single-desk authorities, which went into effect on August, 2012. This represented a major change in how North American malting barley and wheat markets could function and is likely to have important impacts on market participants and Canadian grain exports. However, the full impacts of this change are currently not fully understood, including the potential impacts on contracting for the delivery of malt barley between Great Plains farmers and U.S. maltsters.

While the CWB had a central role in Canadian grain markets, other Canadian federal government agencies and legislative initiatives are also important and likely to remain influential. Two are especially relevant: the 1996 *Canadian Transportation Act* and the Canadian Grains Commission (CGC). The 1996 *Canadian Transportation Act*, which replaced earlier 1983 legislation that directly appropriated federal funds to subsidize grain transportation, imposed annual grain transportation revenue caps for rail companies.[2] Since 2001, the Canadian National Railway and the Canadian Pacific Railway, companies affected by the rate cap, have exceeded these caps on a total of nine occasions, although never by more than 10% (Western Grain Revenue Cap Statistics 2011), suggesting that the policy has been binding. Its removal, therefore, could affect marketing decisions and opportunities, especially if the resulting higher rail rates alter grain procurers' marginal transaction costs.

The 1985 *Canada Grain Act*, the most recent legislation providing authority to the Canadian Grains Commission (originally established in 1912), broadly stipulates that the CGC is responsible for overseeing grain quality and grain handling services. This includes determining grain standards and grades, weighing and inspecting grain, and researching the quality of new grain varieties before the seeds can be registered and sold to Canadian farmers. The CGC's role in variety development and approval for release was especially important when the CWB was the sole marketer and exporter of Canadian

[2] The 1983 *Western Grain Transportation Act* imposed rate regulations and, in turn, subsidized Canadian rail companies.

grains, because the CWB used strict varietal control standards to differentiate and market Canadian wheat and barley in export markets. If the CGC continues to restrict access to new, potentially higher yielding varieties of barley and wheat through the use of criteria such as KVD, then farmers may forgo substantial revenue opportunities. Grain consumers who may have preferences to acquire grains that are produced from customized seeds would also be affected. Accounting for the impacts of CGC policies and transportation regulations after the termination of the CWB's single-desk authority is central to understanding how the framework within which malt barley markets will function under alternative policy structures.

3. A Contracting Model for Malt Barley

Contracting occurs when all parties to a contract expect to benefit from that contract. In this context, the parties are Canadian Great Plains farmers and U.S. maltsters, each of which is assumed to form expectations rationally and to be risk neutral.

3.1 Canadian Farmers' Decisions to Contract with U.S. Maltsters

A risk neutral representative Great Plains farmer is assumed to plant a crop, either malt barley or a competing crop, on one acre of land. The farmer will plant malt barley if the expected returns (net of production and other costs) from contracting for delivery of the crop exceed the expected returns from raising the competing crop—spring wheat—on the land.[3] Effectively, the farmer seeks to maximize expected profits and will grow malt

[3] Spring wheat is a direct substitute in production with barley as both are planted in the spring and accounts for far more acreage than either durum or winter wheat in the Canadian Great Plains Provinces. In 2012, for example, spring wheat's share of total production was 63% in Saskatchewan, 88% in Alberta, and 75% in Manitoba (Canada Grains Council).

barley if the expected net returns from growing barley, π_b, are larger than the expected net returns from growing wheat, π_w. Let y_b and y_w represent expected per acre yields for barley and wheat, P_m the contract price of malt barley, P_f and P_w the expected cash prices of feed barley and wheat, b the cost of growing barley, c the cost of contracting, w the cost of growing wheat, and λ, the selection rate, lies between zero and one. Cost functions are increasing in expected yields and include both variable and fixed costs. The expected net returns or profits from producing malt barley and wheat are:

$$\pi_b = y_b[\lambda P_m + (1 - \lambda)(P_f)] - [b(y_b) + c(y_b)] \qquad (1)$$

$$\pi_w = y_w(P_w) - [w(y_w)] \qquad (2)$$

The farmer is assumed to either contract to grow malt barley or sell spring wheat on the cash market. The selection rate affects the farmer's decision to contract for malt barley because malt barley contracts specify the criteria that must be satisfied for a crop to be accepted for malt. If the farmer's malt barley crop meets these specifications, then the farmer receives a premium price and the farmer's per acre revenue is $y_b P_m$. Otherwise, the farmer sells the barley for feed on the cash market and receives a per acre revenue of $y_b P_f$. Typically, $P_m > P_f$.

Assuming the reasonable assumption that per acre costs of growing malt barley are approximately equal to the costs of growing wheat—that is, $b(y_b) + c(y_b) = w(y_w)$—the farmer will grow malt barley when:

$$\lambda P_m y_b + (1 - \lambda) P_f y_b \geq y_w P_w.$$

This condition can be expressed as:

$$\lambda P_m + (1-\lambda)P_f \geq \frac{y_w P_w}{y_b}. \quad (3)$$

3.2 U.S. Maltsters' Decisions to Contract with Canadian Farmers

Maltsters in the United States will source barley from Canada only if it is profitable for them to do so. Thus the representative U.S. maltster seeks to minimize the cost of acquiring malt barley from farmers. The firm's cost of obtaining a unit of barley from any given farmer is:

$$P_m + z(y_b). \quad (4)$$

where per unit contracting costs, z, may depend on barley yields in the region from which the barley is being sourced. For a U.S. maltster, for Canadian Great Plains barley contracting costs include transportation costs to U.S. facilities, costs due to Canadian variety registration requirements, and the price of the barley. A risk neutral U.S. maltster will contract with Canadian farmers if it is cheaper to purchase barley from Canada than from the United States. Thus, for a U.S. maltster to source barley from Canada, the following condition must be satisfied:

$$P_m^{U.S.} + z^{U.S.}(y_b^{U.S}) \geq P_m^{Can} + z^{Can}(y_b^{Can}) \quad (5)$$

where superscripts identify the country to which each variable applies.

3.3 Conditions for a Feasible Contract

Canadian farmers and U.S. maltsters will contract with each other for malt barley if the minimum malt price a Canadian farmer is willing to accept is less than or equal to the maximum price the U.S. maltster is willing to pay. If yields are different in each region, then contracting occurs when:

$$\frac{1}{\lambda}\left[\frac{y_w\, P_w}{y_b^{Can}} - (1-\lambda)P_f\right] \leq P_m^{Can} \leq P_m^{U.S.} + z^{U.S.}(y_b^{U.S.}) - z^{Can}(y_b^{Can}). \qquad (6)$$

Equation (6) indicates that the likelihood that contracting between the U.S. maltster and a Canadian farmer will occur depends on the expected selection rate, Canadian and U.S. wheat prices, wheat and malt barley yields, and the costs of contracting in the Canadian and U.S. markets. Comparative static effects of shocks to expected yields, prices and selection rates in the Canadian and U.S. markets for wheat and barley are presented and discussed in the technical appendix.

4. Data Description and the Simulation Model

The provisions of the *Marketing Freedom for Grain Farmers Act* were implemented in August of 2012. As a result, currently it is infeasible to directly measure the effects on contracting between U.S. maltsters and Great Plains farmers for the production and delivery of malting barley resulting from the end of the CWB's single-desk authority. However, historical yield, price, and transaction cost information can be used in conjunction with the model presented above to simulate likely market conditions and provide insights about the distributional properties of contracting outcomes. Our analysis focuses on identifying incentives for such contracting in the Great Plains Provinces of Alberta, Manitoba, and Saskatchewan and three U.S. states—Idaho, Montana, and North Dakota. These six regions produce most of the barley grown in each country, accounting for approximately 90% of total Canadian production and 70% of total U.S. production.

Barley and spring wheat yields and prices were obtained from the Canadian Grains Council (CGC) and the USDA National Agricultural Statistical Service (NASS) for the periods 1964–2012 and 1974–2012, respectively.[4] All Canadian yield data were converted from kilograms per hectare to bushels per acre using the CGC's conversion factors: 36.744 bushels of wheat and 45.92 bushels of barley per metric ton. To estimate unbiased yield distributions using historical data, we need to account for technological advances over time. Following Goodwin and Mahul (2004), we first estimate barley and wheat yields in each state or province, j, as a linear function of time t, $y_{jt} = \beta_0 + \beta_1 t + e_{jt}$. Then, we determine the heteroskedasticity-adjusted "detrended" yield as $\tilde{y}_{ijt} = y_{ij,2012} \times (1 + \hat{e}_{ijt}/\hat{y}_{ijt})$, where $\hat{e}_{ijt}$ and $\hat{y}_{ijt}$ represent the predicted residual and yield values from the linear regression.

Monthly price information for U.S. spring wheat, feed barley, and malt barley were obtained from USDA-NASS. Malt barley prices were available for each month through September 2012 from April 1968 in North Dakota, April 1990 in Idaho, April 1991 in Montana. Canadian price data were provided by the CGC for 1965–2012. Under the CWB, farmers in all the Great Plains received payments from pooled accounts, resulting in every farmer facing the same price within a particular marketing year.[5] Different price pools represented the premiums and discounts that farmers received based on the grade of the delivered grain.[6] For example, there were three pools of spring wheat prices (1 CWRS, 2 CWRS, and 3 CWRS) and after 2004, feed barley prices were divided into two pools (1 CW Feed Barley A and 1 CW Feed Barley B). We assume that a typical

[4] Neither the Canadian nor the U.S. barley yield data differentiate between production sold for feed and production sold for malt. Therefore, only the average yields are available and used.

[5] Some price differences did exist based on the location of local grain elevators to adjust for varying transaction costs. However, we were unable to obtain information about location-based price premiums and discounts.

[6] Grain grades represented the quality of the product and were assigned based on the protein content and physical condition of the grain, such as frost damage or sprouted kernels.

farmer is unable to precisely predict the overall quality of their grain and is likely to receive some weighted average across all price pools. Consequently, our Canadian spring wheat and barley prices represent an average value across all pools. Canadian prices are converted into U.S. dollars using the Bank of Canada noon spot rate average exchange rate. These and U.S. market prices are then converted to 2012 constant dollars using the consumer price index provided by the Bureau of Labor Statistics (U.S. Department of Labor).

4.1 Rail Distance and Transportation Cost Estimates

Transporting malt barley from U.S. and Canadian production regions is assumed to be an important variable cost for a U.S. malting firm. Figure 1 shows the Canadian and U.S. growing regions (marked by a filled circle) and the delivery destinations of U.S. brewing companies located in Golden, CO and St. Louis, MO (marked by a star).[7] The approximate routes are represented by lines and are differentiated by the distance from the centroid of a Canadian growing region to major U.S.–Canada border rail hubs (solid line) and from the border to the final destination (dashed and dotted lines). The figure, which shows the proportional distances that grain must travel in Canada and in the United States, indicates that most of the transportation occurs in the United States.

A U.S. malting firm's total transportation costs are assumed to be a function of rail rates and total distance from each source location, which we assume to be the centroid of grain elevator locations in each state or province.[8] Historical Canadian rail

[7] These are the primary locations and headquarters for MillerCoors and Anheuser-Busch.
[8] Elevator locations were collected from the CGC and the BNSF and Union Pacific rail companies. Precise longitude and latitude coordinates for the centroids are available upon request.

rate data were collected from the CGC for the marketing years 1975–2012 and represent the average rate to ship grain from Wilkie, Saskatchewan east to the St. Lawrence Ports on the Great Lakes or west to the Pacific Seaboard. The average of these rates for each marketing year was converted to 2012 U.S. dollars per metric ton per mile using the methodology described above. The USDA Agricultural Marketing Service provided historical weekly U.S. rail rates in dollars per metric ton across different routes during June 2012–February 2013. Canadian rail rates are used for estimating transportation costs for shipping from a Canadian barley growing region to the U.S.–Canadian border, and U.S. rail rates represent marginal shipping costs from the border and from U.S. barley production regions to the U.S. malting firms.

Rail distances for these routes, which are not publicly available, were estimated using nearby road distances. Specifically, we first obtained actual rail distances across 260 location combinations using the Union Pacific online rail distance calculator. For the same location combinations, we used the Google Maps directions feature to determine road distances. Comparing these values to the actual rail distances, we found that, on average, road distances underestimated rail mileage by 11%. Thus we estimated rail distances from the assumed origins and destinations by first obtaining the road distance for each route and multiplying it by a factor of 1.11.

4.2 Accounting for Price and Yield Dependence

Historical price, yield, and transportation cost data can be used to empirically characterize the distributional properties of each variable in a particular region. Then, draws from the specified distributions would represent possible production and market realizations, which can be used to identify when conditions are favorable for malt barley contracting. Following an extensive literature characterizing agricultural yield and price distributions (for example, Nelson 1989, Anibal 1989, Smid 2004, Mitra 2008), we test two sets of competing hypotheses for each yield and price variable distribution in each region. Specifically, we test whether historical yields in region *j* are more adequately characterized by a beta or normal distribution and whether historical spring wheat and barley prices and rail rates are more adequately characterized by a lognormal or normal distribution. To assess the robustness of each distributional assumption, we perform four different tests: Kolmogorov-Smirnov, Cramer-von Mises, Anderson-Darling, and Chi-square.[9]

Table 1 presents a summary of distributional fit statistics for Canadian and U.S. price, yield, and transportation cost data. If at least two tests failed to reject the null hypothesis of a particular distribution, then that distribution was used. If both assumed distributions were not rejected or both were statistically rejected at a 10% level, then a beta distribution was assumed to characterize yields and a lognormal distribution to characterize prices. The results of the distribution tests indicate that all crop prices and transportation costs can be characterized by lognormal distributions, and yields can be characterized by a beta distribution in all but three locations (Idaho, North Dakota, and Manitoba). After determining each variable's density function, empirical distribution functions were used to estimate the parameters that provided the best fit to the observed

[9] Except the Chi-square test, the distribution assessments are based on the empirical distribution function (EDF). See D'Agostino and Stephens (1986) for a rigorous discussion about EDFs and these distribution test procedures.

historical data (see Johnson, Kotz, and Balakrishnan 1994 for a description of distributional parameters). Table 2 provides descriptive statistics of the estimated marginal distributions for each yield, price, and transportation cost variable and the estimated distributional parameters.

In addition to determining historical marginal distributions, it is also important to consider the potential for correlations among prices and yields within and across locations. 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). Correlation tests across yields and prices indicate the potential for three types 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.[10] Interestingly, there is no statistical evidence of dependence among spring wheat yields and prices and among barley yields and prices. Wheat yields and prices may be uncorrelated because wheat is a global commodity and changes in U.S. and Canadian production are not sufficiently large to have significant effects on world wheat prices. Chambers (2004), who also reports weak interdependence among barley prices and yields, argues that barley prices are more closely linked to corn prices because corn and barley are substitutes in animal feeds.

We use a copula function to account for these relationships and simulate values from the joint multivariate distributions of yields and prices. Copulas provide a relatively

[10] The correlation test results are not shown for brevity, but they are available from the authors.

simple and 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. For example, the joint yield distribution across locations can be characterized as:

$$f(y_1, y_2, \dots, y_j) = C(\theta; f_1(y_1), f_2(y_2), \dots, f_j(y_j)) \quad (7)$$

where $f(y_1, y_2, \dots, y_j)$ represents the joint distribution of yields across j locations, $f_j(y_j)$ is the marginal distribution of yields in location j, $C(\cdot)$ is the copula function, and θ is the copula function's dependence parameters, which characterize the dependence structure among the marginal density functions. By estimating empirical Spearman correlation structures among yields and among prices and using them to parameterize the copula function, we are able to simulate individual yield and price outcomes for each location while preserving historical rank correlations among those variables within and across locations.

5. Simulation Results

Using a Gaussian copula function, we simulate 5,000 yield, price, and transportation cost values for each region, which represent sets of *ex ante* expectations for malt barley contracting participants.[11] These data are used to determine the lower and upper price bounds under which contracting in the deregulated North American malt barley markets is possible. The lower bound represents the price threshold below which a farmer would

[11] See Trivedi and Zimmer (2007) for a description of the Gaussian copula. Using other copula specifications can more accurately represent the dependence structure in the tails of the joint distribution. However, our research focuses on understanding contracting decisions under typical market conditions rather infrequent outcomes. A Gaussian copula function, therefore, is used primarily as a mechanism for preserving historical dependence structures rather than making strong distributional tail assumptions.

not be willing to accept a contract and the upper bound is the highest price at which a U.S. malting firm is willing to offer a contract. Specifically, we evaluate the condition

$$\frac{1}{\lambda}\left[\frac{\hat{y}_w \hat{P}_w}{\hat{y}_b^{Can}} - (1-\lambda)\hat{P}_f\right] \leq P_m^{Can} \leq$$
$$\hat{P}_b^{U.S.} \frac{\hat{y}_b^{U.S.}}{\hat{y}_b^{Can}} + \frac{1}{\hat{y}_b^{Can}}[(\hat{t}^{U.S.} \hat{d}^{U.S.})\hat{y}_b^{U.S.} - (\hat{t}^{Can}\hat{d}^{Can} + \hat{t}^{U.S.} \hat{d}^{U.S.})\hat{y}_b^{Can}], \quad (8)$$

where, for any price or yield variable, *x*, $\hat{x}$ represents a simulated value; $\hat{t}^k$ 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); and all other variables are as described above.

For each set of simulated prices, yields, and transportation costs, we evaluate whether or not the upper bound exceeds the lower bound in equation (8) to determine whether conditions are favorable for U.S. malting firms to contract with Canadian farmers. The evaluations are carried out for farmers in each Great Plains Province relative to farmers in Idaho, Montana, or North Dakota. Contracting conditions are evaluated for selection rates ranging from 51% to 99%. Gustafson (2006) suggests that selection rates in the range of 51% to 65% are typical of dryland conditions, while selection rates between 80% and 95% are more typical for malt barley planted on irrigated land. Selection rates from 66% to 84% are assumed to represent atypically favorable dryland conditions. We restrict the simulated data to include only observations where the minimum farm price for malting barley is greater than the price of feed barley. The contract decision is based on farmers' and firms' expectations about future price and yield conditions, and it is unlikely that farmers will choose to establish a contract if they believe that feed barley prices will exceed malt barley prices.[12]

5.1 Contracting in the Absence of the CWB Single-Desk Authority

In the absence of a CWB single-desk grain marketing authority, we find that market conditions would sometimes be conducive for contracting between U.S. malting firms and Great Plains farmers, but these conditions do not occur frequently. For each selection rate, conditions favorable for contracting between Canadian farmers and U.S. maltsters occur most frequently between the Missouri maltster and farmers in Manitoba. On average, such conditions occur in between 21% and 33% of the total simulations. Favorable conditions for contracting between the Colorado maltster and Manitoba farmers occur in only 11% to 19% of the total. For farmers in Saskatchewan, favorable conditions occurred in 17% to 27% of the simulations for contracting with the Missouri maltster and in 14% to 23% of the simulations for contracting with the Colorado maltster. Favorable conditions for contracting are observed least frequently for farmers in Alberta, occurring in only 6% to 14% of the simulations for contracting with either the Missouri or Colorado maltster.

Figure 2 shows the proportion of total simulations for which market conditions would make contracting feasible between farmers in each of the three Great Plains Provinces and the two U.S. malting firms over the range of selection rates. As shown by

[12] The assumed distribution for feed barley prices resulted in the barley feed price exceeding the estimated minimum malt barley price in about 20% of the simulated market conditions. However, these values were generated from the tails of the estimated price distributions and, in fact, feed barley prices are observed to exceed malt barley prices much less frequently than that. The historical data indicate that in the United States, such price inversions have occurred once during the previous 30 years and did not occur in Canada. Therefore, because we wish to model normal market conditions, we discard these observations.

the comparative static results presented in the Appendix, the frequency with which favorable conditions occur is positively correlated with selection rates. *Ceteris paribus*, the expected benefits from planting malt barley increase as the probability of making malt becomes higher. Figure 2 also shows that conditions favorable for contracting consistently occur more frequently for contracts between the Missouri maltster and Saskatchewan and Manitoba farmers. On average, conditions favorable for contracting with the Missouri maltster occur 4 to 12 percentage points more frequently than for contracting with the Colorado maltster. This result reflects that relative to U.S. producers with whom the U.S. maltsters would otherwise contract, Missouri maltsters would have greater cost advantages to contract with Canadian farmers from these two provinces. The low frequency with which conditions favorable for contracting occur between either of the U.S. maltsters and farmers in Alberta suggests that transaction costs have a dominant role in the U.S. maltsters' contracting decisions.

Table 4 presents the average of the lower bound prices that occur when conditions are favorable for contracting over the range of selection rates. The results indicate that the average lower bound prices at which contracting occurs in Saskatchewan are higher than those in Manitoba and Alberta, and the lowest average lower bound prices are observed in Alberta. Table 4 also shows the average upper bounds on the prices U.S. maltsters would offer farmers from each Great Plains Province. The average upper bound price offered by the Colorado maltster is lowest for farmers in Alberta, who are most distant from the plant, higher for farmers in Manitoba, and highest for farmers in Saskatchewan, who are closest to the plant. The average upper bound price offered by the Missouri maltster is also lowest for farmers in Alberta, who are most distant from that plant, higher for farmers in Saskatchewan, and highest for farmers in Manitoba, who are closest to the Missouri plant. These results indicate the importance of location and transportation costs in the contracting decision.

5.2. Contracting in a Deregulated Freight Rate Environment

The importance of transportation costs suggests that relaxing the revenue caps on Canadian grain rail transportation by the 1996 *Canadian Transportation Act* could have measurable effects on the likelihood of contracting. Following Vercammen (1999), we assume that in the absence of a CWB single-desk authority, grain transportation rates in Canada would be deregulated and increase by approximately 4% for shipments of barley to the U.S.–Canadian border. The cost of shipping barley from the U.S.–Canadian border to maltsters in Colorado or Missouri, however, would not be affected by changes in Canadian transportation policies. The change in Canadian freight rates only affects the upper bound prices in equation (8) and we recalculate these prices to evaluate the effects increased Canadian freight rates on the frequency of contracting between U.S. maltsters and Great Plains farmers.

Figure 3 presents the simulation results over the range of selection rates, showing the frequencies with which contracting occurs without the CWB single-desk authority but when the current cap on Canadian freight rates is imposed and when those freight rates increase by 4%. The deregulation of Canadian grain freight rates has only a trivial effect (less than a 1 percentage point reduction) on the frequency with which contracting would occur at every selection rate. As suggested in the Figure 1 map and by the shipping cost estimates reported in Table 3, the result reflects the fact that freight costs incurred in Canada only account for approximately 15% of the total delivery costs from the Great Plains Provinces to the two U.S. maltsters. However, although the direct impacts of changes in Canadian grain transportation policies on shipping costs and the frequency with which contracting may occur are small, those changes could have indirect effects by altering the relative costs and returns to farmers associated with other commodities such as spring wheat.[13]

5.3 The Effects of Relaxing Varietal Control Policies for Spring Wheat

The likelihood that contracting for malt barley will occur between U.S. maltsters and Canadian farmers also depends on spring wheat yields, which affect the minimum price at which those farmers will contract for malt barley production. Spring wheat yields in the Great Plains Provinces appear to have been adversely affected by the application of varietal controls such as those associated with kernel visual distinguishability. For example, Ulrich (1987) suggests that less strict varietal restrictions on spring wheat could increase Canadian farmers' opportunities to plant higher yielding spring wheat varieties with substantial effects on realized yields. To simulate the effects of relaxing the CGC criteria applied for the release of spring wheat varieties, we re-specify the parameters of the spring wheat marginal distributions for Alberta, Manitoba, and Saskatchewan to reflect the distributional properties of average spring wheat yields of Idaho, Montana and North Dakota. The re-specified spring wheat yield distributions demonstrate a 14%

[13] For example, the 1995 elimination of Canadian rail grain transport subsidies effectively increased the costs of grain transport and led to an increase in exports to the United States instead of offshore markets and an increase in grain production for domestic consumption (Doan 2003).

increase in expected Canadian wheat yields. Lastly, because brewers often specify that proprietary barley varieties must be planted, barley yields are assumed to be unaffected by changes in varietal regulation policies.[14]

Figure 4 shows the frequency with which contracting occurs over the entire range of selection rates under the assumption that CGC varietal controls remain restrictive and the frequency when those criteria for spring wheat are relaxed. The simulation results indicate that the frequency with which contracting occurs substantially decreases when varietal controls are deregulated and spring wheat yields increase. The likelihood that Saskatchewan farmers will contract for malt barley production and delivery with either the Missouri or Colorado maltsters falls by 11 percentage points. For Manitoba farmers, the likelihood that contracting will take place declines by 6 percentage points for the Missouri maltster and by 5 percentage points for the Colorado maltster. The initially low relative likelihood of contracting between Alberta farmers and either U.S. maltster declines by less than 1 percentage point.

These results indicate that, compared to freight rate deregulation, access to higher yielding spring wheat varieties is likely to have a larger impact on malt barley contracting between Canadian farmers and U.S. maltsters. Moreover, while deregulated higher grain freight rates are likely to reduce the net returns to Canadian farmers (and their economic welfare) from both malt barley and spring wheat production, increased access to spring wheat varieties has a different effect. Contracting with U.S. brewers for malt barley becomes less likely because higher wheat yields would make the crop's production more

[14] In fact, the marginal distribution parameters for historical Canadian barley yields are not statistically different from those for the U.S. production regions.

profitable, increasing the opportunity costs of raising malt barley. The net effect would almost surely be an increase in economic welfare for Canadian Great Plains farmers who raise spring wheat and barley.

6. Conclusions

This study examines the incentives for contracting for malt barley between farmers in the Canadian Great Plains Provinces and U.S. brewing companies in the absence of a CWB with single-desk authorities for malt barley. We develop a theoretical model of contracting decisions between Canadian Great Plains farmers and U.S. maltsters that accounts for market conditions, including crop prices, crop yields, uncertainty about crop quality (reflected in selection rates), and transactions costs. A simulation model based on the theoretical analysis is developed, which is calibrated using historical data on crop prices and yields in the Canadian Provinces of Alberta, Manitoba, and Saskatchewan and the U.S. states of Idaho, Montana and North Dakota. Using Monte Carlo simulations in which draws are made form a copula function, the empirical model is used to estimate the frequency with which Canadian farmers and U.S. maltsters will have incentives to contract for malt barley.

Canadian Great Plains farmers may face new opportunities for marketing grains in the absence of a CWB with single-desk marketing authority. 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. maltsters occur relatively infrequently. The likelihood that market conditions will be favorable to contracting ranges from 11% to 33% in Manitoba and from 14% to 27% in Saskatchewan, with higher frequencies associated with higher selection rates. The likelihood that contracting will occur in Alberta ranges from 6% to 14%, 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.

The likelihood that contracting between Canadian Great Plains farmers and U.S. maltsters will take place also depends on other aspects of grain market regulation in Canada. If the revenue caps established by the 1996 *Canadian Transportation Act* were discontinued and rail costs for shipping Canadian grain were to rise by 4% (as estimated by Vercammen 1999), then Canadian malt barley contracting opportunities would not be significantly affected. This result reflects the fact that the rail costs of shipping barley to the U.S.–Canadian border constitute a relatively small proportion of the total cost of moving grain to the two U.S. maltsters. However, ending the transportation revenue cap could have substantial adverse impacts on farm gate prices for Canadian spring wheat exported through Vancouver or the Great Lakes by raising rail freight rates for spring wheat. These potential effects are not accounted for in this study but have been considered by others (for example, see Fulton 2006).

Varietal release policies for spring and other wheat classes may also affect the likelihood that contracting for malt barley will occur between Canadian Great Plains farmers and U.S. maltsters. However, in the new institutional environment, a continued focus on restrictive criteria for the release of new varieties through the Canadian Grains

Commission's varietal approval process may constrain technology adoption by Canadian farmers, resulting in foregone revenue opportunities (Ulrich 1987). Modifying the varietal approval process to allow registration of higher yielding wheat varieties is likely to improve the returns to planting wheat, but would also increase the opportunity costs of planting malt barley and raise the minimum price at which a Canadian Great Plains farmer would contract for the delivery of barley with brewers. The results of the simulation analysis indicate that these changes would substantially reduce the frequency with which contracting occurs in Manitoba (by an average of 5 percentage points) and Saskatchewan (by an average of 11 percentage points).

Sources Cited

Alston, J. M., and R. Gray. 2000. State trading versus export subsidies: The case of Canadian wheat. *Journal of Agricultural and Resource Economics*, *25*(1), 51-67.

Alston, J. M., C.A. Carter, and V.H. Smith. 1993. Rationalizing agricultural export subsidies. *American Journal of Agricultural Economics*, *75*(4):1000-1009.

Anibal, M. E. 1989. *Estimation Of Crop Yield Variation And Its Use In Farm Financial Planning* (No. 11038). Michigan State University, Department of Agricultural, Food, and Resource Economics.

Canada Grains Council. 2012. Online Handbook. http://canadagrainscouncil.ca/subscriber/CGCSection/www_show_handbook (accessed December 2012).

Canadian Transportation Agency. 2011. Western Grain Revenue Cap Statistics. http://www.otc-cta.gc.ca/eng/publication/western-grain-revenue-cap-statistics (accessed October 25, 2012)

Carter, C. A., R. M. A. Loyns, and D. Berwald. 1998. Domestic costs of statutory marketing authorities: The case of the Canadian Wheat Board. *American Journal of Agricultural Economics*, *80*(2):313-324.

Carter, C. A., and V. H. Smith. 2001. The potential impacts of state trading enterprises on world markets: The exporting country case. *Canadian Journal of Agricultural Economics*, *49*(4):429-439.

Chambers, W. 2004. *Forecasting Feed Grain Prices in a Changing Environment*. United States Department of Agriculture.

D'Agostino, R., and M. Stephens. 1986. *Goodness-of-Fit Techniques*. New York: Marcel Dekker.

Fulton, M. E. 2006. *The Canadian Wheat Board in an Open Market: The Impact of removing the Single-Desk Selling Powers.* University of Saskatchewan, Knowledge Impact in Society (KIS) Project.

Goodwin, B. K., and O. Mahul. 2004. Risk modeling concepts relating to the design and rating of agricultural insurance contracts. *World Bank Policy Research Working Paper*, (3392).

Goodwin, B. K., and T. C. Schroeder. 1994. Human capital, producer education programs, and the adoption of forward-pricing methods. *American Journal of Agricultural Economics*, *76*(4):936-947.

Johnson, N. L., S. Kotz, and N. Balakrishnan. 1994. *Continuous Univariate Distributions-1, Second Edition.* New York: John Wiley and Sons.

Lavoie, N. 2005. Price discrimination in the context of vertical differentiation: An application to Canadian wheat exports. *American Journal of Agricultural Economics 87*(4):835-854.

McCorriston, S., and D. MacLaren. 2006. "The economic effects of state trading enterprises: Market access and market failure." Paper presented at the International Association of Agricultural Economists annual meeting, Queensland, August 12-18.

Mitra, S., and J. M. Boussard. 2008. "Storage and the volatility of agricultural prices: A model of endogenous fluctuations." *Bronx, NY, Department of Economics, Fordham University*, *21*.

Nelson, C. H., and P. V. Preckel. 1989. The conditional beta distribution as a stochastic production function. *American Journal of Agricultural Economics*,*71*(2):370-378.

Smid, M. 2004. "Normal approximation of the distribution of the equilibrium price in markets with random demand and supply" (No. 0411001). EconWPA.

Trivedi, P., and D. Zimmer. 2007. *Copula Modeling: An Introduction for Practitioners.* Hanover, MA: now Publishers.

Ulrich, A., W. H. Furtan, and A. Schmitz. 1987. The cost of a licensing system regulation: An example from Canadian prairie agriculture. *Journal of Political Economy 95*(2):160-178.

United States Department of Agriculture: Agricultural Marketing Services. Grain Transportation Report. http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateA&navID=AgriculturalTransportation&leftNav=AgriculturalTransportation&page=ATGrainTransportationReport&description=Grain%20Transportation%20Report%20(GTR) (accessed February 12, 2013).

United States Department of Agriculture: National Agricultural Statistics Service. Quick Stats. http://quickstats.nass.usda.gov/ (accessed December 2012).

United States Department of Labor: Bureau of Labor Statistics. 2013. Consumer Price Index – All Items. http://data.bls.gov/cgi-bin/surveymost (accessed February 14, 2013).

Vedenov, D. 2008. "Application of copulas to estimation of joint crop yield distributions." Paper presented at AAEA annual meeting, Orlando, FL.

Veeman, M. M. 1987. Marketing boards: The Canadian experience. *American Journal of Agricultural Economics*, *69*(5):992-1000.

Vercammen, J. 1999. Impact on western grain rail rates from an elimination of the legislated rate cap. *Canadian Journal of Agricultural Economics*. *47*(3):251-264.

Xu, W., G. Filler, M. Odening, and O. Okhrin. 2010. On the systemic nature of weather risk. *Agricultural Finance Review*. *70*(2):267-284.

Table 1: Marginal Distribution Assumptions and *p*-values for Yield, Price, and Transportation Cost Variables

	Test for H_0: Normal Distribution				**Test for H_0: Beta Distribution**				
	K-S	**C-vM**	**A-D**	**C-S**	**K-S**	**C-vM**	**A-D**	**C-S**	**Chosen Distribution**
U.S. Yields									
Idaho barley	0.092	0.211	0.239	0.003	0.086	0.002	0.001	0.001	Normal
Montana barley	0.079	0.010	0.005	0.024	0.003	0.001	0.001	0.006	Beta
North Dakota barley	0.150	0.241	0.167	0.171	0.025	0.015	0.008	0.001	Normal
Canadian Yields									
Alberta spring wheat	0.150	0.250	0.187	0.097	0.500	0.500	0.500	0.529	Beta
Manitoba spring wheat	0.150	0.250	0.250	0.307	0.015	0.002	0.001	0.016	Normal
Saskatchewan spring wheat	0.150	0.250	0.154	0.001	0.250	0.250	0.178	0.030	Beta
Alberta barley	0.150	0.250	0.250	0.193	0.129	0.144	0.075	0.141	Beta
Manitoba barley	0.150	0.250	0.250	0.067	0.118	0.104	0.126	0.099	Beta
Saskatchewan barley	0.012	0.040	0.043	0.083	0.107	0.250	0.250	0.503	Beta
	Test for H_0: Normal Distribution				**Test for H_0: Lognormal Distribution**				
U.S. Prices									
Idaho malt barley	0.010	0.005	0.005	0.001	0.150	0.113	0.049	0.084	Lognormal
Montana malt barley	0.010	0.005	0.005	0.001	0.150	0.449	0.260	0.001	Lognormal
North Dakota malt barley	0.010	0.005	0.005	0.001	0.010	0.005	0.005	0.001	Lognormal
Cost to ship grain by rail	0.010	0.005	0.005	0.001	0.010	0.005	0.005	0.001	Lognormal
Canadian Prices									
1 CWRS	0.010	0.005	0.005	0.001	0.089	0.049	0.068	0.372	Lognormal
2 CWRS	0.012	0.005	0.005	0.001	0.022	0.033	0.032	0.053	Lognormal
3 CWRS	0.012	0.005	0.005	0.001	0.150	0.060	0.087	0.643	Lognormal
1 CW feed barley	0.029	0.006	0.005	0.003	0.150	0.136	0.141	0.840	Lognormal
Cost to ship grain by rail	0.127	0.049	0.041	0.182	0.150	0.500	0.500	0.258	Lognormal

Notes: K-S represents the Kolmogorov-Smirnov test, C-vM is the Cramer-von Mises test, A-D is the Anderson-Darling test, and C-S is the Chi-Square test. Distributional assumptions are tested using historical data from the Canada Grains Council and United States Department of Agriculture and then a marginal distribution for simulation is chosen if at least two of the four distributional tests fail to reject the null hypothesis. If the null hypothesis is rejected for both distribution assumptions, then the beta distribution is assumed for yields and the lognormal distribution is assumed for prices. 1 CWRS, 2 CWRS, 3 CWRS, and 1 CW feed barley represent price pools for Canadian spring wheat and barley, respectively.

Table 2: Marginal Distributions and Parameters for Yield, Price, and Transportation Cost Variables

	Distribution	Mean	Std. Dev.	Alpha	Beta
U.S. Yields					
Idaho barley	Normal	93.137	13.106		
Montana barley	Beta			2.428	1.710
North Dakota barley	Normal	64.807	14.560		
Canadian Yields					
Alberta spring wheat	Beta			2.244	1.059
Manitoba spring wheat	Normal	42.778	6.226		
Saskatchewan spring wheat	Beta			2.131	0.935
Alberta barley	Beta			2.867	1.809
Manitoba barley	Beta			1.753	1.456
Saskatchewan barley	Beta			2.075	1.508
U.S. Prices					
Idaho malt barley	Lognormal	4.583	0.900		
Montana malt barley	Lognormal	4.458	0.854		
North Dakota malt barley	Lognormal	5.336	2.493		
Cost to ship grain by rail	Lognormal	0.053	0.023		
Canadian Prices					
1 CWRS	Lognormal	8.937	4.397		
2 CWRS	Lognormal	8.655	4.276		
3 CWRS	Lognormal	8.228	4.157		
1 CW Feed Barley	Lognormal	5.169	2.562		
Cost to ship grain by rail	Lognormal	0.073	0.013		

Notes: All yields are in bushels per acre and all prices are in 2012 U.S. dollars. 1 CWRS, 2 CWRS, 3 CWRS, and 1 CW feed barley represent price pools for Canadian spring wheat and barley, respectively. The costs to ship grain by rail are in USD per metric ton per mile.

Table 3: Total Malt Barley Shipping Distances and Costs by Origin and Final Destination

	Canada		*United States*		*Total*	
	Rail Distance	**Rail Costs**	**Rail Distance**	**Rail Costs**	**Rail Distance**	**Rail Costs**
To Golden, CO						
Idaho	–	–	917.978	0.056	917.978	51.580
Montana	–	–	810.112	0.056	810.112	45.519
North Dakota	–	–	925.843	0.056	925.843	52.022
Alberta	359.557	0.074	1,010.112	0.056	1,369.670	83.207
Saskatchewan	247.152	0.074	897.753	0.056	1,144.905	68.624
Manitoba	180.826	0.074	1,138.202	0.056	1,319.028	77.256
To St. Louis, MO						
Idaho	–	–	1,792.135	0.056	1,792.135	100.698
Montana	–	–	1,664.045	0.056	1,664.045	93.500
North Dakota	–	–	1,080.899	0.056	1,080.899	60.734
Alberta	359.557	0.074	1,864.045	0.056	2,223.602	131.188
Saskatchewan	247.152	0.074	1,294.382	0.056	1,541.534	90.911
Manitoba	180.826	0.074	1,068.539	0.056	1,249.365	73.342

Notes: Grain source locations in each state and province are the average latitude and longitude of grain elevators using elevator location data obtained from BNSF, Union Pacific, and the Canada Grains Council. Delivery locations are the MillerCoors plant located in Golden, CO and the Anheuser-Busch plant located in St. Louis, MO. Estimated rail distances are in miles and costs are mean estimated rail costs in USD per metric ton per mile.

Table 4: Malt Barley Lower and Upper Bound Contract Prices: Mean Values and Standard Deviations by Province and Destination

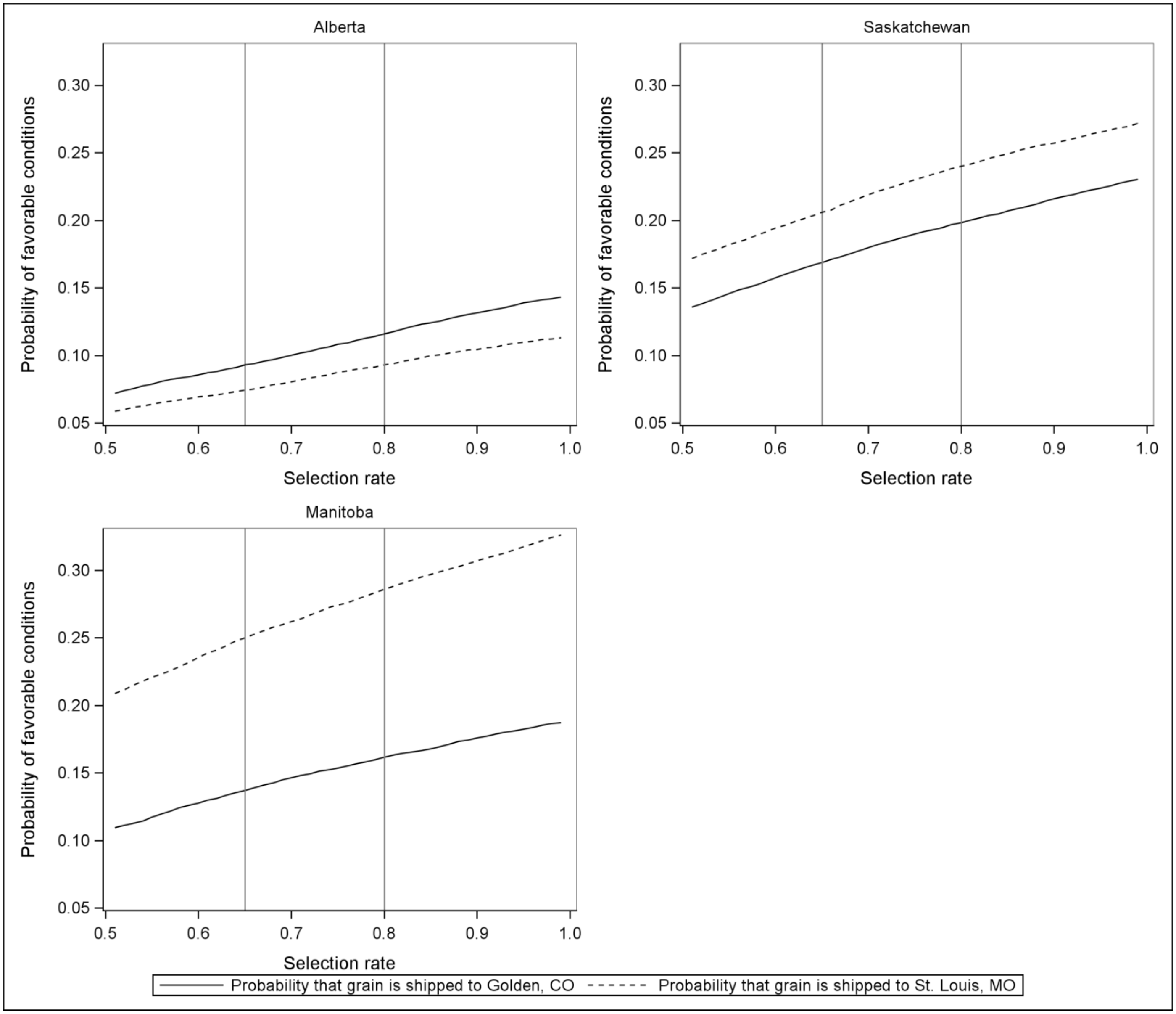
		Farm Price								*Firm Price*
Origin	**Destination**	**Dryland Farming Selection Rate**				**Irrigated Farming Selection Rate**				
		0.51	**0.55**	**0.60**	**0.65**	**0.80**	**0.85**	**0.90**	**0.95**	
Alberta	Golden, CO	4.273	4.280	4.252	4.275	4.286	4.260	4.258	4.264	4.382
		(1.886)	(1.896)	(1.885)	(1.913)	(1.950)	(1.936)	(1.935)	(1.960)	(1.867)
	St. Louis, MO	4.557	4.557	4.570	4.569	4.551	4.559	4.543	4.532	4.083
		(1.995)	(2.026)	(2.064)	(2.064)	(2.093)	(2.113)	(2.111)	(2.108)	(1.831)
Saskatchewan	Golden, CO	5.034	5.030	5.039	5.028	4.972	4.965	4.957	4.943	4.801
		(2.486)	(2.492)	(2.519)	(2.520)	(2.534)	(2.545)	(2.556)	(2.553)	(1.920)
	St. Louis, MO	5.377	5.338	5.309	5.289	5.233	5.213	5.190	5.177	5.069
		(2.789)	(2.753)	(2.746)	(2.753)	(2.752)	(2.743)	(2.736)	(2.741)	(1.861)
Manitoba	Golden, CO	4.469	4.454	4.466	4.474	4.467	4.451	4.454	4.448	4.583
		(2.077)	(2.073)	(2.101)	(2.113)	(2.136)	(2.130)	(2.149)	(2.152)	(1.902)
	St. Louis, MO	5.002	4.965	4.917	4.904	4.832	4.812	4.796	4.787	5.424
		(2.551)	(2.511)	(2.470)	(2.474)	(2.451)	(2.449)	(2.437)	(2.441)	(1.861)

Notes: Farm prices are the means of the lowest prices Canadian farmers would be willing to accept when malt barley contracts are possible; that is, when farm price is less than the highest price a U.S. maltster is willing to pay (firm price). Firm prices are malting firms' mean maximum willingness to pay. Contract prices are in USD per bushel.

Figure 1: Malt Barley Shipment Source and Delivery Locations and Approximate Rail Shipping Routes

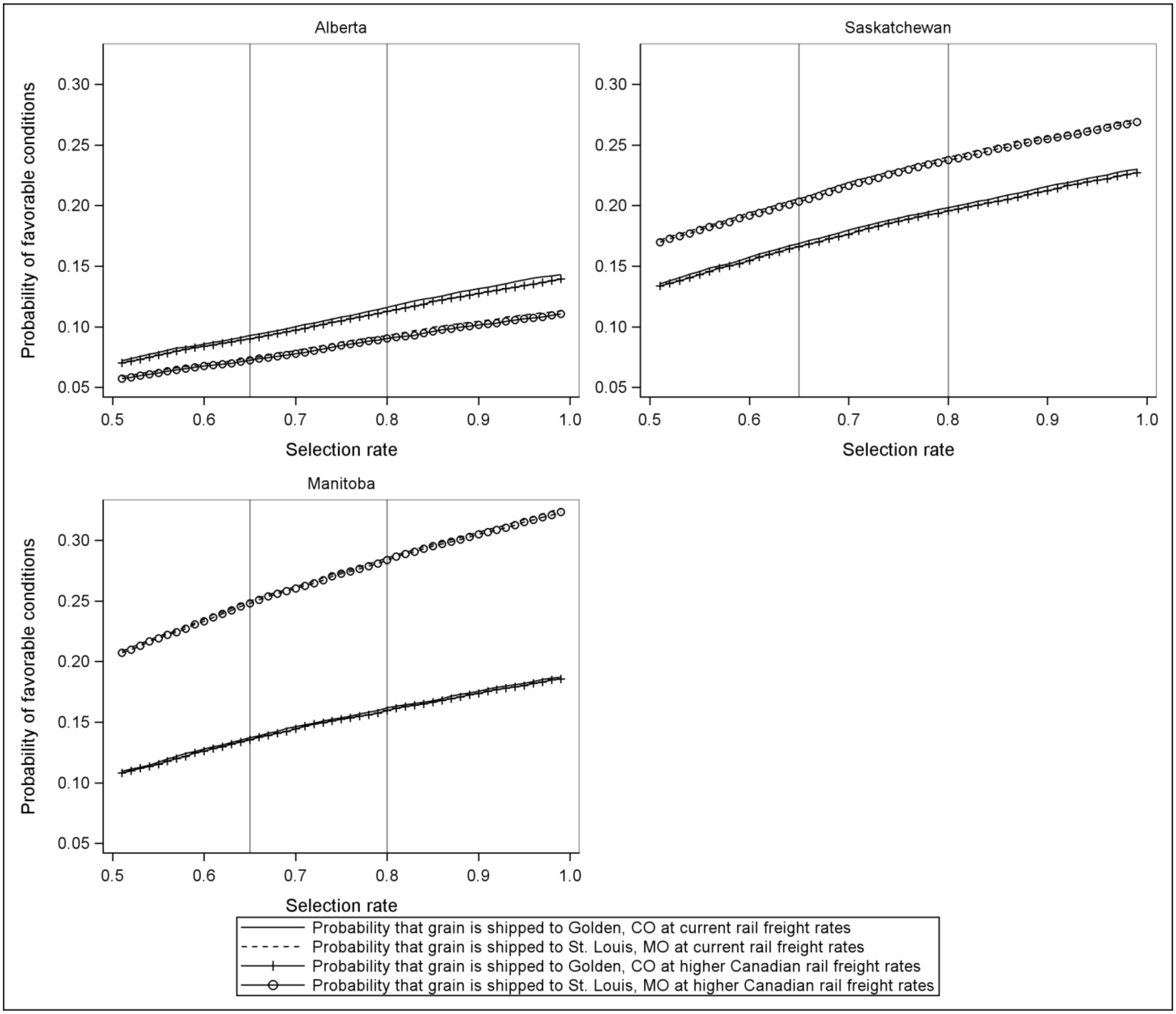
Notes: Grain source locations in each state and province are the average latitude and longitude of grain elevators using elevator location data obtained from BNSF, Union Pacific, and the Canada Grains Council. Delivery locations are the MillerCoors plant located in Golden, CO and the Anheuser-Busch plant located in St. Louis, MO.
Source: Figure constructed by the authors.

Figure 2: Probability of Favorable Contracting Conditions by Province



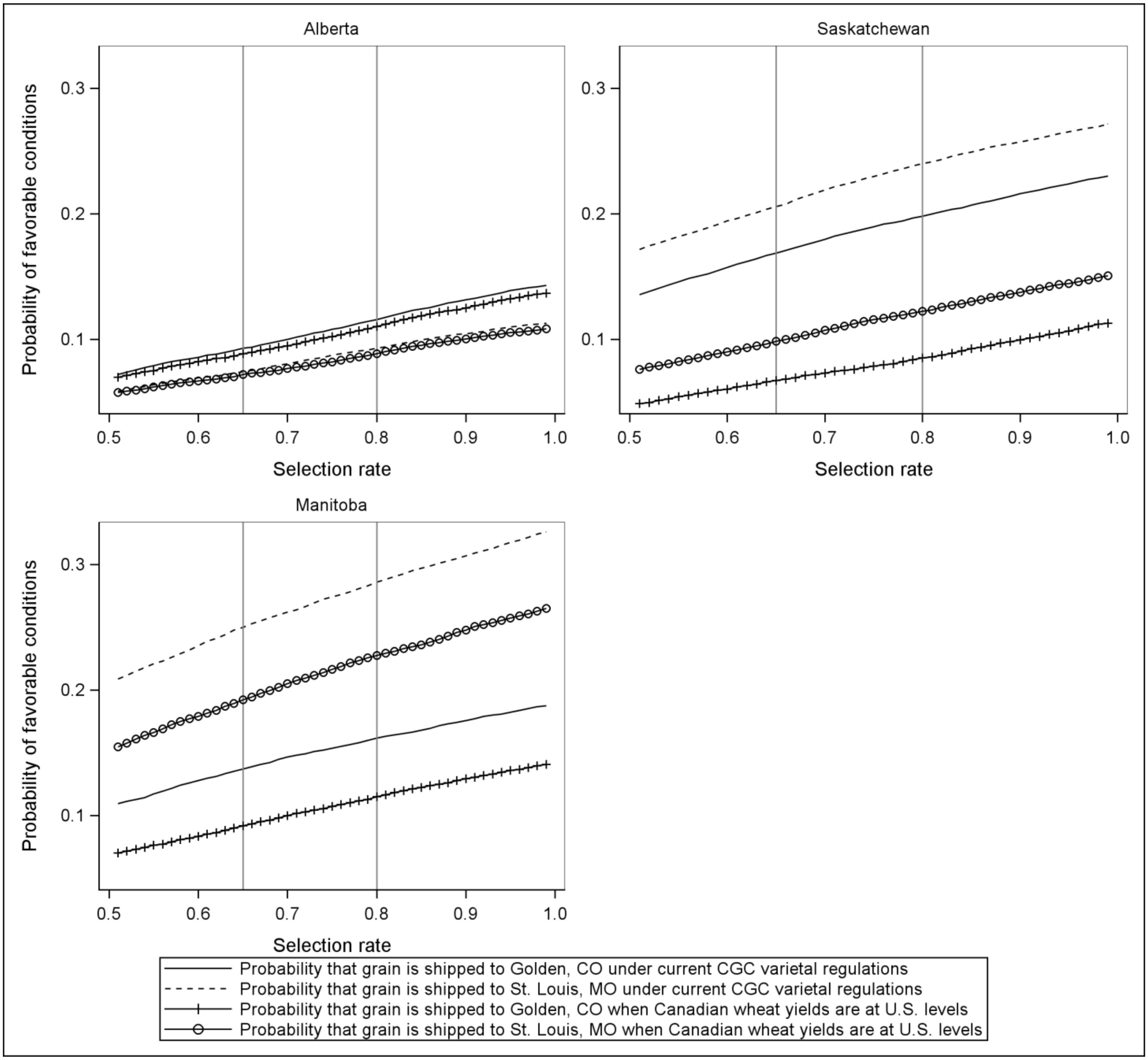
Notes: Conditions conducive to contracting occur when Canadian Great Plains farmers and U.S. maltsters expect prices, yields, and selection rates to be when the contract price for producing and delivering malt barley in Canada rather than the United States is greater than the lower bound on prices that Canadian farmers are willing to accept and less than the upper bound on prices that U.S. malting firms are willing to pay. The vertical line at the 0.65 selection rate denotes the expected upper bound for dryland production and vertical line at the 0.8 selection rate denotes the expected lower bound for irrigated production.
Source: Figure constructed by the authors using simulated barley and spring wheat yields and prices and rail rates.

Figure 3: Probability of Favorable Contracting Conditions by Province in a Deregulated Freight Rate Environment



Notes: Conditions conducive to contracting occur when Canadian Great Plains farmers and U.S. maltsters expect prices, yields, and selection rates to be when the contract price for producing and delivering malt barley in Canada rather than the United States is greater than the lower bound on prices that Canadian farmers are willing to accept and less than the upper bound on prices that U.S. malting firms are willing to pay. Removal of the Canadian grain rail transportation revenue cap is expected to increase the cost of shipping grain in Canada. The vertical line at the 0.65 selection rate denotes the expected upper bound for dryland production and vertical line at the 0.8 selection rate denotes the expected lower bound for irrigated production.
Source: Figure constructed by the authors using simulated barley and spring wheat yields and prices and rail rates.

Figure 4: Probability of Favorable Contracting Conditions by Province after Relaxing Varietal Control Policies for Spring Wheat



Notes: Conditions conducive to contracting occur when Canadian Great Plains farmers and U.S. maltsters expect prices, yields, and selection rates to be when the contract price for producing and delivering malt barley in Canada rather than the United States is greater than the lower bound on prices that Canadian farmers are willing to accept and less than the upper bound on prices that U.S. malting firms are willing to pay. The vertical line at the 0.65 selection rate denotes the expected upper bound for dryland production and vertical line at the 0.8 selection rate denotes the expected lower bound for irrigated production.
Source: Figure constructed by the authors using simulated barley and spring wheat yields and prices and rail rates.

Appendix: Contracting Conditions and Comparative Statics Results

Equation (6), restated in this appendix as equation (A1), defines the conditions under which Canadian farmers and U.S. brewers contract for the production and delivery of malt barley; that is,

$$\frac{1}{\lambda}\left[\frac{y_w\, P_w}{y_b^{Can}} - (1-\lambda)P_f\right] \leq P_m^{Can} \leq P_m^{U.S.} + z^{U.S.}(y_b^{U.S.}) - z^{Can}(y_b^{Can}). \tag{A1}$$

Contracting occurs when the upper bound on the price a U.S. maltster is willing to pay Canadian farmers, $P_m^{U.S.} + z^{U.S.}(y_b^{U.S.}) - z^{Can}(y_b^{Can})$, exceeds the lower bound on the price the Canadian farmer is willing to accept, $\frac{1}{\lambda}\left[\frac{y_w\, P_w}{y_b^{Can}} - (1-\lambda)P_f\right]$. The lower bound on the contract price is conditional on the selection rate, λ, Canadian wheat and barley yields, y_w and y_b, and Canadian wheat and feed barley prices, P_w and P_f. The upper bound depends on U.S. malt barley prices, $y_b^{U.S.}$, and Canadian and U.S. contracting costs, $z^{U.S.}$ and z^{Can}.

Let $P_{m,min} = \frac{1}{\lambda}\left[\frac{P_w y_w}{y_b^{Can}} - (1-\lambda)P_f\right]$ define the lower bound on the feasible contract price and $P_{m,max} = P_m^{U.S.} + z^{U.S.}(y_b^{U.S.}) - z^{Can}(y_b^{Can})$ define its upper bound. The derivatives of the lower bound with respect to P_w, y_w, P_f, y_b^{Can}, and λ are as follows:

$$\frac{\partial P_{m,min}}{\partial P_w} = \frac{y_w}{\lambda\, y_b^{Can}} > 0, \tag{A2}$$

$$\frac{\partial P_{m,min}}{\partial y_w} = \frac{P_w}{\lambda y_b^{Can}} > 0, \tag{A3}$$

$$\frac{\partial P_{m,min}}{\partial P_f} = -\frac{1-\lambda}{\lambda} < 0, \tag{A4}$$

$$\frac{\partial P_{m,min}}{\partial y_b^{Can}} = -\frac{P_w}{\lambda\left(y_b^{Can}\right)^2} < 0, \tag{A5}$$

$$\frac{\partial P_{m,min}}{\partial \lambda} = 1 - \frac{P_w y_w}{P_f y_b} \lesseqgtr 0. \tag{A6}$$

Increases in the price of wheat, P_w, and wheat yields, y_w, increase wheat revenues and the opportunity cost of growing malt barley, resulting in an increase in the minimum malt barley contract price a farmer is willing to accept. However, increases in the price of feed barley, P_f, and barley yields, y_b, increase expected barley revenues and decrease the minimum contract price. The sign of $\frac{\partial P_{m,min}}{\partial \lambda}$ is ambiguous; however, under the most likely expected market condition that the expected revenue from selling wheat is greater than the expected revenue from barley sold on the feed market, $1 < \frac{P_w y_w}{P_f y_b}$, increases in the selection rate, λ, are expected to increase the likelihood of contracting; that is, $\frac{\partial P_{m,min}}{\partial \lambda} < 0$. The derivatives of the upper bound contract price, $P_{m,max}$, with respect to $P_m^{U.S.}$, $z^{U.S.}$ and z^{Can} are obvious and require no further discussion.