Export Spread, Farmer Revenue and Grain Export Capacity in Western Canada

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Starting in the 2013-14 crop year, a lack of export capacity resulted in substantial increases in the spread between farm and port FOB prices in western Canada. This created a very difficult situation for the farming community. We calculate that this situation reduced grain farmers' income over the 2013-14 and 2014-15 crop years by approximately C$6.7 billion. Clearly, the grain handling and transportation system has problems and capacity to move grain is one of them. To evaluate the need for grain export capacity expansion, we forecast future grain production using a rational expectations model to estimate future export spreads and subsequent rents. We find that without capacity improvements, the expected cost of limited grain export capacity could exceed C$5.6 billion over the next decade. Capacity improvements on the order of a 25% increase will likely mitigate this issue in the future.

INTRODUCTION

Capacity constraints in transportation can have a significant impact on spatial price relationships within commodity markets. To this end, the law of one price suggests that if a commodity can be moved from point A to B, then any difference in the price of the commodity at the two points should reflect only transportation costs. However, when commodity arbitrage is capacity constrained, spatial price spreads in the market must increase so as to ration the available transportation capacity. Any such price adjustments can have very significant economic and distributional impacts.

Transportation markets can become capacity constrained from both supply and demand shocks. For example, commodity analysts continually monitor labor strikes, natural disasters, and wars that disrupt transportation and/or reduce capacity. Given its importance in commodity market arbitrage, investment in transportation infrastructure is often perceived as a prerequisite for economic development.

In the 2013 crop year, record Canadian grain production levels combined with a later start to harvest, an unexpectedly early and cold winter, poor production forecasts, and a low carryover of grain from the previous year resulted in a slower than normal movement of grain, creating a transitional grain transportation crisis in western Canada.[1] As grain companies lowered their cash bids for grain to ration available capacity, the price spread between FOB port and country elevator cash bid (the so-called export spread) levels in western Canada increased significantly, peaking at up to three times above normal, or historical levels. In March 2014, the Canadian government responded with new regulations, one of which enforced a level of minimum weekly grain movements by both railways. Effectively, it took until July 2015 for ending stocks and export spread levels to return to historical levels. These two years of elevated export spread levels came at a cost to Canadian prairie grain farmers.

One may argue that the grain transportation crisis buttressed by the record 2013 crop yield was an isolated incident that is not likely to be repeated again, rendering any efforts to improve grain export capacity as unnecessary. However, we believe this to be an empirical issue that will be governed by future export demand as well as future grain transportation capacity.

Using price and quantity data for the 2012-13, 2013-14, and 2014-15 crop years, we estimate ex post impacts of limited grain export capacity. Looking forward, the ex ante component of our study addresses the need for future grain export capacity, a task that begins with forecasting grain production over the 2016-2026 period. We develop a model that incorporates the derived demand for grain exports within a spatial market, consisting of three major Canadian production regions and four export points for grain. As a benchmark in this section, we first estimate farmers' potential losses assuming no grain export capacity improvements. We then examine how this loss might be mitigated with additional export capacity.

The remainder of this study is organized as follows. The next section provides a short review of the relevant literature. The third section presents the analytic background on demand for grain handling and transportation in Canada (GH&T). The fourth and fifth sections present our ex post and ex ante analyses, respectively. The last section provides a conclusion along with some policy implications.

LITERATURE REVIEW

This study borrows its foundations from two related streams in the economics literature. The first investigates arbitrage and spatial price spreads, while the other studies storage and temporal price differentials or basis.

To start, the work of Samuelson (1952) and Takayama and Judge (1964) developed spatial price equilibria in linear and quadratic programming frameworks, respectively. Subsequently, Richardson (1978) examined commodity arbitrage between the U.S. and Canada, while later work saw Ardeni (1989) and Goodwin et al. (1990) examine the law of one price for international wheat markets. In turn, various aspects of goods arbitrage, spatial price differentials and equilibrium related to agricultural markets were examined in the work of Spiller and Wood (1988), Sexton et al. (1991), Goodwin and Schroder (1991), Faminow and Benson (1990), Baulch (1994, 1997), and Fackler (1996).

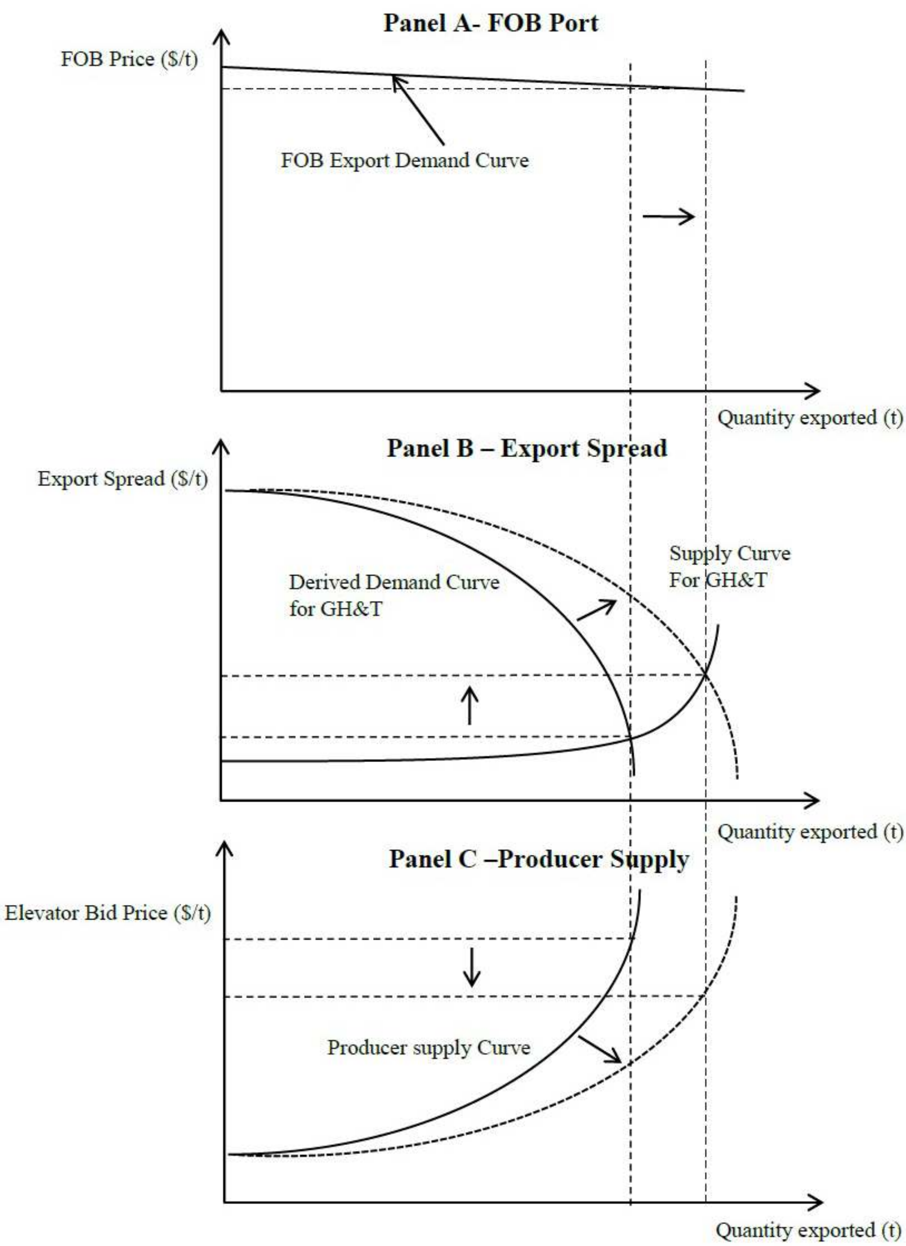
Research inspired by Working's (1949) "theory of the price of storage" explored various aspects of storage and temporal price differentials. The subsequent related literature on agricultural markets is vast. For example, Brennan (1958) is widely cited for his work on the supply of storage, while Williams and Wright (1991) modeled storage in commodity markets. Other relevant studies in this area include Weymar (1966), Ehrich (1969), Tilley and Campbell (1988), Sarwar and Anderson (1989), and McKenzie (2005). Most recently, Tadasse et al. (2016) explored the causes of food price spikes, while Caves et al. (2000) and von Braun (2009) discussed mitigating price spikes in wholesale and food markets, respectively. Collectively these studies highlight that disruptions in commodity transportation that limits its arbitrage can have significant impacts on both spatial price spreads and relative price levels.

DERIVED DEMAND FOR GRAIN HANDLING AND TRANSPORTATION AND THE ROLE OF STORAGE

Here, we define the export spread as the difference between country elevator cash bids in Saskatchewan and FOB port prices in Vancouver.[2] We offer that this is an approximate measure of the per (metric) tonne (MT) revenue or gross margin earned by grain companies to purchase grain from farmers on the prairies and load it onto a vessel at port.[3] To earn this gross margin, the grain companies must incur the cost of primary elevation, cleaning and storage, rail freight, terminal elevation, and fobbing. Given this, we also offer that an opportunity for profitable arbitrage by a grain company occurs when export capacity is constrained.

To provide better understanding of the impact of an export capacity constraint in this context, GH&T services are modeled in a derived demand framework, as illustrated in Figure 1. Here, the FOB Vancouver demand has minimal slope, reflecting the fact that Canada is largely a price taker in world grain markets (Schmitz and Furtan 2000).

Figure 1: The Impact of Large Capacity Constrained Supply on Export Spread Levels and Producer Prices



Examining this diagram, the producer supply curve (Panel C) is the price at which farmers on aggregate are willing to sell any specific quantity of grain to elevators (in Saskatchewan) for export. Intuitively, the price intercept of the supply curve indicates the cash price that the most desperate producer would accept if exports were limited to just a single tonne for the region. As the quantity purchased for export increases, the producers' offer price also increases. As this quantity approaches the total available grain, higher prices cannot attract additional deliveries and, thus, the producers' supply curve becomes vertical.

The derived demand for GH&T services (Panel B), which is the vertical difference between the FOB demand curve (Panel A) and the producer supply curve (Panel C), represents the maximum willingness of a broker to have grain handled and transported from producer delivery to FOB port (Vancouver) position. Further, the supply of GH&T services is shown in Panel B. Once again, the price intercept of the supply curve represents the minimum export spread charge by any grain company to export the first tonne offered. The long and nearly horizontal portion of the GH&T supply curve represents the quantity that is moved at posted tariff rates. As the quantity moved approaches GH&T export capacity, the GH&T supply curve slopes upward since the exporter must incur additional costs to secure additional export capacity. This supply curve becomes nearly vertical as short-term options to increase export capacity are exhausted.

The export spread charges or price for GH&T services is determined by where the demand and supply curves for GH&T intersect (Panel B). If this intersection occurs where capacity constraints are not binding, the export spread charges are at normal or historical levels. In this case, bid prices in the province of Saskatchewan for example, reflect the Vancouver FOB price minus GH&T costs, so that grain companies earn normal profits from exporting grain.

When there is a large producer supply, GH&T capacity constraints become binding and the situation changes dramatically. This is illustrated by the dashed supply curve in Panel C. In this case, the intersection of derived demand and the supply of GH&T occurs in the more vertical portion of the GH&T supply curve, where the export spread is far higher than normal and the cash bids are reduced relative to Vancouver FOB prices.

The GH&T rents, which are the differences between the average cost of GH&T and the export spread charges, accrue to grain companies or contract holders that have secured access at lower (tariff based) rates. Average freight rates in Canada are currently constrained by the maximum revenue entitlement policy, known as the MRE (Nolan and Peterson 2015). Due to this constraint, railways cannot capture additional system revenue by increasing their freight rates.[4] Producers who do not contract sales face lower prices for the grain they export or sell locally, incurring a cost equal to the increase in export spread multiplied by the quantity of their sales.

Several forms of arbitrage related to the law of one price[5] contribute to higher export spread impacts across markets. First, as long as some of the product is exported at elevated export spread levels, the price at which producers are willing to sell to local processors also reflects the same lower cash bids. Second, grain companies have an incentive to purchase grain types and grades with higher export spread levels. This grain company arbitrage occurs until all grades and commodities earn similar export spreads per tonne. Finally, producers have a choice between selling grain at the current export spread versus storing and selling grain at some future date, with the expected return from current and future sales differing by storage costs. When export spread levels increase, both current and future contract prices are affected.

Given these various forms of arbitrage that characterize efficient markets, increased export spreads tend to be pervasive, affecting nearly all sales within the export area equally. Nevertheless, some producers should be able to avoid the effects of lower cash bids by contracting prior to export spread increases or finding alternative markets for delivery. We note that in the 2013-14 crop year, some Canadian producers near the U.S. border were able to limit the effects of increased export spreads by instead trucking their grain to less congested U.S. shipping points. However, CGC delivery statistics suggest that at that time, the vast majority of Canadian grain was still delivered to local grain elevators for export (CGC 2015). If a similar situation occurs in the future, it remains to be seen whether or not Canadian farmers will use this potential outlet to try to further alleviate these effects. Therefore, we conduct this analysis assuming that Canadian farmers in the foreseeable future will not suddenly start transporting vast quantities of export bound grain south of the border in response to increased export spreads at Canadian ports.

The theory presented in this section is the primary framework we use to measure the effects of GH&T capacity constraints. To further illustrate what occurred in this market, the next section calculates export spread levels and foregone revenues over 2012-13, 2013-14, and 2014-15 crop years. The basis for these calculations is the work done by Gray (2015).

EX POST ANALYSIS: FOREGONE GRAIN PRODUCER REVENUE

Actual excess export spread levels are used to estimate the income effects of the 2013-14 transportation situation for western Canadian grain producers. The export spread levels are presented in Figure 2. As reported in Table 1, losses to producers are calculated based on the deliveries of grain in western Canada during the periods of August 1 to December 31, January 1 to March 31, and April to July 1 for both the 2013-14 and 2014-15 crop years.[6] Wheat, barley, canola, peas, and oats are the only grains included in these calculations.

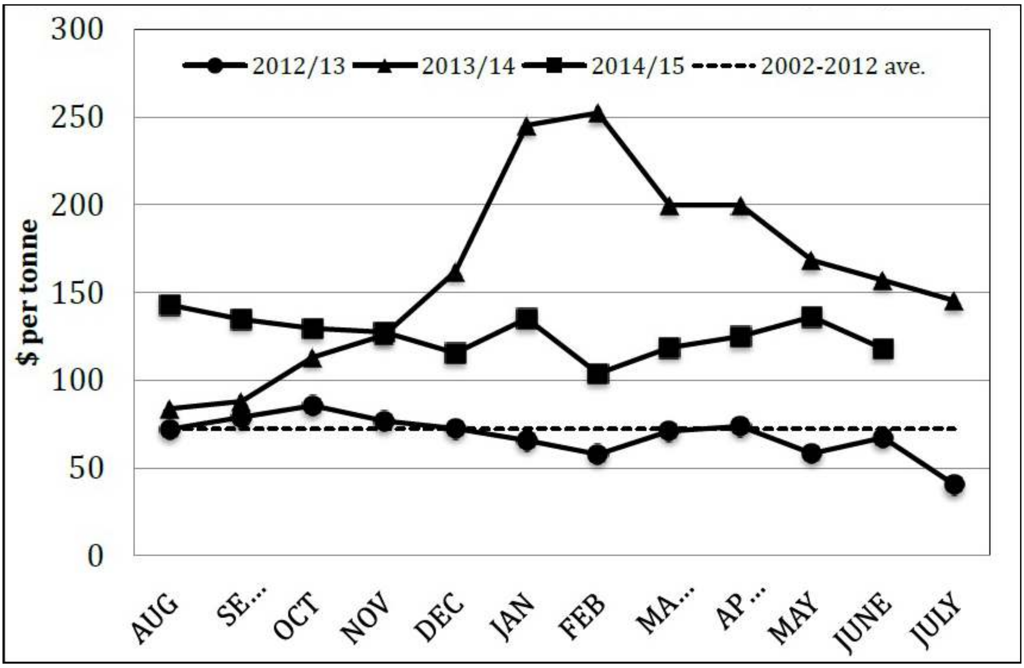
Farmer deliveries are multiplied by our estimates of excess export spread levels in order to quantify the overall impacts. In our first calculation, the export spread levels that existed at the time of delivery are assumed to apply to all grain delivered during the period. This metric describes the total export rents generated because of limited export capacity. Given our assumptions, this amount is estimated to be C$6.7 billion. However, we caution that this amount should be considered an upper bound because many producers were able to avoid paying the above normal export spread by using other means, including delivering to U.S. points, or using forward-price and forward-contract deliveries.

In our second calculation, we assume that all grain delivered reflects the export spread which existed 12 weeks earlier. Here, the loss to Canadian producers is estimated to be C$6.3 billion. While this calculation represents an extreme amount of forward contracting in the market, it illustrates the idea that the export spread effect only becomes slightly smaller when forward contracting is formally taken into account.

In our third sample calculation, we assume that 20% of all grain deliveries reported were able to escape the effect of a higher export spread. This means all grain sales had their export spread set a full three months in advance. Even in this very conservative case, the estimated losses to Canadian grain producers still exceeded C$5.05 billion.

The figures reported in Table 1 are based on several simplifying assumptions. First, we assume that the increase in export spread is solely due to lack of export capacity. Given a clear comparison to the C$72 export spread that existed in the 2012-13 crop year when there was adequate export capacity, we offer that any excess over C$72 can be reasonably attributed to a lack of export capacity. The return toward a more normal export spread level by June 2015, as delivery pressures decreased, also supports our assumption.

Figure 2: Estimated Vancouver FOB – Saskatchewan Cash Bid Export Spread (C$/T)



Notes: Export spread is calculated as the difference between Vancouver FOB prices and Saskatchewan cash bid prices.
Source: Vancouver FOB prices: AAFC (2014), Saskatchewan cash bid prices: Saskatchewan Ministry of Agriculture (2014).

Second, we assume that the FOB price is fixed and not positively affected by reduced exports. Demand factors suggest that buyers pay more for Canadian grains when export volumes are reduced, particularly for types and classes of grain where Canada is a major supplier. However, when export flows are reduced, the deferred export quantities are additional grain for future sale, so the net price effect is likely to be limited. Looking at the price data for example, the FOB prices for Canadian western red spring wheat atypically traded at a significant discount to the equivalent quality dark northern spring wheat out of Portland, C$25/tonne in 2013-14 and C$42/tonne in the 2014-15 crop year (Gray 2015). This suggests buyers pay less for grain with an insecure delivery schedule, which we assume just offsets any increase in the world price, due to the increased export spread. However, if there were some short-term net positive effects on FOB prices, then our estimated producer losses would be overestimations of actual producer losses.

Table 1: Estimated Grain Producer Income Impact of Congestion Related Excess Export Spread in Western Canada, 2013-14 and 2014-15

	2013-2014 Crop year			2014-2015 Crop year			
	Aug-Dec	Jan-Mar	Apr-Jul	Aug-Dec	Jan-Mar	Apr-Jul	Total
Farm Deliveries (000T) *	21.80	11.86	18.92	22.85	12.72	15.00	103.15
All Sold at Prevailing Export Spread**							
Ave Excess Export Spread($/MT)	$51.49	$143.53	$77.67	48.63	59.97	34.94	64.88
Total Export Rents ($Million)	$1,123	$1,702	$1,470	$1,111	$763	$524	**$6,692**
All sold at Export Spread 12 weeks prior^							
Excess Export Spread (t - 12weeks)($/MT)	$6.02	$75.78	$130.82	58.62	48.48	56.82	61.21
Producer Losses ($Million)	$131	$899	$2,475	$1,339	$617	$852	**$6,314**
80% sold at export spread 12 weeks prior^^							
Excess Spread (t - 12weeks)($/MT)	$6.02	$75.78	$130.82	$58.62	$48.48	$56.82	0.75
Producer Losses ($Million)	$105	$719	$1,980	$1,071	$493	$682	**$5,051**

Source: Authors Calculation, Figure 3, and CANSIM Table 0010043 (Statistics Canada 2015b).
* Farm Deliveries of wheat, oats, barley, canola, peas, western Canada.
**Excess export spread is estimated to be Vancouver FOB – Sask. Cash bids for wheat - $72/MT see Figure 1 for calculation and sources.
^ Excess export spread reported for 12 weeks prior to delivery is used to estimate impact.
^^ This lower bound estimate assumes that only 80% of producer deliveries are impacted and all export spread is priced 12 weeks prior to delivery.

Finally, these calculations assume that the wheat export spread is reflected in other grains (barley, canola, oats and peas). From an arbitrage perspective, this is a reasonable assumption because if the export spread on another grain is significantly higher than wheat, a company should move more of that product until the export spread becomes equal among the grains. Similarly, if the export spread was lower on some other grain, a grain company would use its available capacity to ship wheat.

EX ANTE ANALYSIS

Our ex ante analysis first estimates prairie farmers' potential losses from limited export capacity, and then estimates the cost savings available through capacity improvement.

Methodology

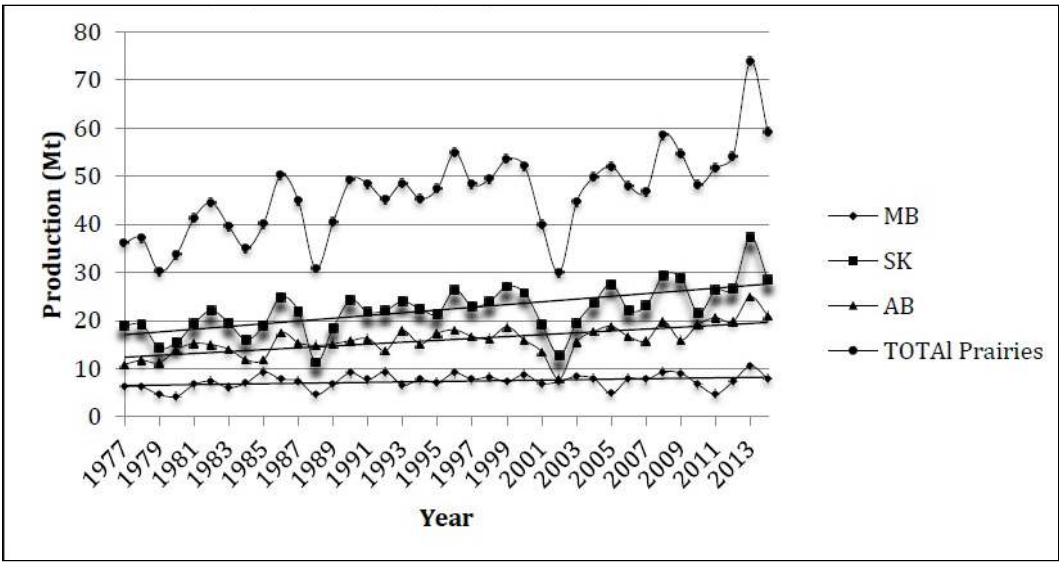
To find the effect of limited export capacity on export spread levels and farmers' revenue, we must first forecast future production. Production forecasts, along with their computed probability distribution functions (PDFs) are then used in a rational expectations storage model to calculate future expected export spread levels as well as farmers' expected losses due to limited export capacity. The rational expectations storage model is founded upon the literature on storage theory in commodity markets (Williams and Wright 1991). The next section illustrates the methodology.

Future Production

This analysis uses historical data to forecast future crop production in western Canada. Crops used in the analysis include spring wheat, winter wheat, durum wheat, barley, canola, soybeans, oats, rye, flaxseed, chick peas, lentils, and dry peas.

As presented in Figure 3, production levels in the three Canadian Prairie provinces are highly correlated. Therefore, the aggregate data from Alberta, Saskatchewan, and Manitoba are used to forecast future production.

Figure 3: Production of Grains, Oilseeds, and Pulses in Manitoba (MB), Saskatchewan (SK) and Alberta (AB), 1977-2014



Source: Statistics Canada (2014).

An autoregressive (AR) time series model is used to estimate the magnitude and length of autocorrelation in our data, along with the importance of a time trend in our crop production time series (Allen 1994; Greene 2002, Chapter 19; Campbel et al. 2002). The AR forecasting model used here takes the following form:

(1) $Y_t = \beta_0 + \beta_1 Y_{t\text{-}1} + \beta_2 Y_{t\text{-}2} + \beta_3 T + \beta_4 D_{1988} + \beta_5 D_{2002} + \beta_6 D_{2013} + \epsilon_t$

where Y_t, $Y_{t\text{-}1}$, and $Y_{t\text{-}2}$ are the current, first lag, and second lag of production levels, respectively; T represents time trend; D_{1988}, D_{2002}, and D_{2013} are dummy variables for years with significantly lower or higher than average production levels; and ϵ_t represents the error term.

Schwarz Criterion suggests an optimal lag length of two for our production data. The time trend variable, T, is critical for estimating the rate of yield improvement over time. To ensure that abnormally high or low production levels do not affect the estimated parameter on the time trend variable, dummy variables are incorporated for the extreme prairie crop years 1988, 2002, and 2013. The observations for these three years are included when calculating the variance for the PDFs to ensure that our estimates do not ignore the possibility of the occurrence of extraordinarily good or bad crop years, also meaning there are fewer concerns about under-representing risk in the model.

Probability Distribution Functions for Grain Production

Production forecasts do not provide us with the probability of running into a limited export capacity problem given the storage levels of previous years and current production levels. A simulation model is developed to produce PDFs for both current and future production of Canadian grain (Billingsley 1979). A Jarque-Bera test cannot reject the null hypothesis of normal distribution. Therefore, the PDFs are assumed to be normally distributed and are computed in the following manner:

a. Calculate the parameters (i.e., mean and variance) of the de-trended historical production data, from 1977 to 2014.
b. Produce random draws within a normal distribution with the parameters calculated in part *A*.
c. Add the first lag parameter, β_1, estimated in Equation 1 to the random draws calculated in part *B*.
d. Add the second lag parameter, β_2, estimated in Equation 1 to the result of part *C*.
e. Add the time trend variable parameter, β_3, estimated in Equation 1 to the result of part *D*.

The first two steps of our simulation approach resemble a bootstrapping method as they use a known sample to generate random draws (Efron and Tibshirani 1993). However, our approach also incorporates the time trend and any potential serial correlation estimated in Equation 1 into the PDFs - parameters β_1, β_2, and β_3 shift the PDFs. Thus, PDF of grain production in any given year has a random component (generated in steps a and b) and a deterministic component (added in steps c, d, and e). The merit of the approach described above is that it allows us to easily calculate the conditional probability of having to store grain in any given year given the production and storage levels of previous years. This is explained further in the next section.

Expected Export Spread with Rational Expectations

Storage theory in commodity markets developed by Williams and Wright (1991) is used as the basis of the rational expectations storage model developed in this section. We assume that total export capacity is also constrained by current railway capacity. Therefore, we presume that exportable supply levels that are higher than export capacity result in storage. The existence of storage costs, which are incurred by farmers, also creates an opportunity for grain companies to increase export spread levels. For instance, in year *t,* farmers have no choice but to either accept a cash price P_t^f or pay a storage cost SC_t and sell their crop the next year at the price P_{t+1}^f of .[7] Therefore, in year *t,* farmers are indifferent between P_t^f and P_{t+1}^f- SC_t. Therefore, farm price (i.e., farmers' received price) in year *t* can be derived from the following condition:

(2) $$P_t^f = P_{t+1}^f - SC_t$$

Thus, equation 2 links farm price in year *t* to farm price in year *t*+1 and is valid if and only if there is storage in year *t*. However, farm price in year *t*+1 depends on farm price in year *t*+2 and storage cost in year *t*+1. Therefore, farm price in year *t*+1 can be found with the following:

(3) $$P_{t+1}^f = P_{t+2}^f - SC_{t+1}$$

Therefore, assuming storage continuously occurs for *n* consecutive years, the price in year *n* is found as follows:

(4) $$P_{t+n}^f = P_{t+n+1}^f - SC_{t+n}$$

Furthermore, Equation 2 can be rewritten as follows:

(5) $P_t^f = P_{t+n+1}^f - \sum_{i=t}^{t+n} SC_i$

Given that the cash price in any year is equal to a constant world price, P^w minus export spread, and assuming that the export spread returns to the normal level after n years, equation 5 can be rearranged as:

(6) $P^W - B_t = P^W - \bar{B} - \sum_{i=t}^{t+n} SC_i$

where B_t is the export spread level in year t and is $\bar{B}$ the normal export spread level. Equation 6 can also be rewritten to find the export spread level in year t:

(7) $B_t = \bar{B} + \sum_{i=t}^{t+n} SC_i$

Equation 7 states that the export spread level in any given year is equal to the normal or average export spread plus all storage costs that farmers incur for the crop produced in that year. However, farmers cannot be certain about how many consecutive years there will be positive storage from the crop produced in year t. The number of years with positive storage from crops produced in year t depends on future production levels. Therefore, farmers form rational expectations regarding future storage cost (Muth 1961). To incorporate these rational expectations, equation 7 needs to be rewritten as:

(8) $E[B_t] = \bar{B} + \sum_{i=t}^{t+E[n]} SC_i = \bar{B} + E[\sum_{i=t}^{t+n} SC_i]$

Where these expectations are based on the probability distribution of future production.

For this analysis, we assume export spread levels return to normal after a maximum of two years.[8] Therefore, we use the reduced from of equation 8:

(9) $E[B_t] = \bar{B} + E[\sum_{i=1}^{2} SC_i]$

Note that the expectations still play a critical role even in the case of only two years. As highlighted previously, a good crop year is very likely to be followed by another relatively good crop year. Therefore, the probability of having to store grain for more than one year is higher in good crop years, so we can expect export spread levels to increase as the probability of having to store grain increases.

Given the theory background provided above, we next describe how the expected export spread is calculated when it is assumed that storage occurs for a maximum of two years. Assuming *EC* is export capacity, *DU* is domestic consumption, and the subscript t represents time, expected export spread can be calculated as described in Table 2.

Table 2: Expected Export Spread Calculations

Production Level in year *t* (Y_t)	**Expected Export Spread Level in year *t* ($E[B_t]$)**
Zero to (EC_t+DU_t)	Normal Export Spread ($\bar{B}$)
Over (EC_t+DU_t)	Normal Export Spread ($\bar{B}$) + Expected Storage Cost ($E[\sum_{i=1}^{2} SC_i]$)

Export spread is effectively determined by the most "desperate to sell grain" farmers. Therefore, if there is positive storage, regardless of the amount, export spread increases by the expected storage cost. As the amount of storage increases, the probability of having to store for more than one year increases. This increases the expected storage cost. Expected storage cost can be formulated as:

$$(10)\ E[\textstyle\sum_{i=1}^{2} SC_i] = SC_1 + P.SC_2$$

where P is the probability of having to store grain for more than one year (i.e., probability of having to store grain in year 2 or more generally year t+1) and is calculated as:

$$(11)\ \mathrm{P}(Y_{t+1} > EC_{t+1} + DU_{t+1} - S_t) = 1 - F_{Y_{t+1}}(EC_{t+1} + DU_{t+1} - S_t) = 1 - \int_{-\infty}^{EC_{t+1}+DU_{t+1}-S_t} f_{Y_{t+1}} dY_{t+1}$$

where is Y_{t+1}, EC_{t+1}, and DU_{t+1} are production level, export constraint, and domestic use in year $t + 1$, and S_t is storage level in year t. F and f represent PDF and cumulative distribution function (CDF), respectively. The PDF has a normal distribution:

$$(12)\ f_{Y_{t+1}} \sim N(\mu_{t+1}, \sigma^2)$$

where μ_{t+1} and σ^2 are expected production level and variance in year t+1. To calculate the probability in equation 11, we need the expected value and the variance of the PDF for production levels in year t+1. This expected value is the "expected production" level for year t+1. Typically export spread becomes an issue when there are significant carry-over stocks from one good year to another relatively good year. We assume farmers are aware of this fact and take it into account when forming their expectations of future production. This assumption is reflected in the AR model through the first lag.

If the production level in year t is above its mean, then β_1 (%) of the difference from the mean is added to the expected production in year t+1. To incorporate this in the calculation of farmers' expectations, expected production in year t+1 is calculated as:

$$(13)\ \mu_{t+1} = \bar{Y}_{t+1} + \beta_1(Y_t - \bar{Y}_t)$$

where $\bar{Y}_t$ and $\bar{Y}_{t+1}$ are estimates of average production in years t and t+1, respectively. Here we note that Y_t is the production level in year t, and β_1 is the autocorrelation coefficient obtained from the AR model.

Farmers' expected losses from limited export capacity are calculated as the weighted average of above normal export spread levels, with probabilities of the occurrence of various expected export spread levels used as weights.

DATA AND MODEL ASSUMPTIONS

We assume that grain is transported by rail (mostly) and truck from the regions of Alberta (AB), Western Saskatchewan (West SK), Eastern Saskatchewan (East SK), and Manitoba (MB) to export markets through West, East, and South ports. Descriptions of origins and destinations are presented in Table 3.

Table 3: Origins and Destinations for Grain in the LP Model

Origins	Destinations
Alberta	West-Vancouver and Prince Rupert
West Saskatchewan	East- Thunder Bay
East Saskatchewan	South-Minneapolis
Manitoba	South- Pacific Northwest (through Minneapolis)

Tables 4 and 5 present the data used in the model. Exportable grain supplies for each of the four regions are calculated as total production minus total domestic use, based on their historical share in total production and domestic use.

Table 4: Export, Rail and Domestic Use Capacity for the 3 Provinces

	Capacity (MMT)
Export-West Coast- Vancouver and Prince Rupert	27
Export-East Coast	11.25
Export-South-Minneapolis	1
Export- South-PNW (through Minneapolis)	3.75
Rail Capacity	40
Domestic Use (MMT)	20

Source: CGC (2015), AAFC (2015), Quorum Corporation (2015), Statistics Canada (2015b), Authors' Calculations.

Port and rail capacities are assumed to be represented by the record high 2013-14 movement levels. As reported in Table 4, total west, east, and south port export capacities add up to 43 million (metric) tonnes (MMT), whereas total rail capacity is computed as 40 MMT. Therefore, we assume that current export capacity is constrained by rail movements at a level of 40 MMT. Also, average domestic consumption of grain is estimated to be approximately 20 MMT per year. Further, we assume trucking can be used to export a maximum of 4.75 MMT of grain to the south (Quorum 2015).

If export capacity is limited, grain must be stored for at least one year. The cost of storing grain is assumed to be C$60/tonne per year (Table 5). This value reflects behavior observed in the 2013-14 and 2014-15 crop years when producers could either sell their grain at the current elevated export spread (as reported in Table 1 and Figure 2) or contract for delivery in the next crop year at a normal export spread.[9] While this storage cost is somewhat higher than intra-year storage rates, inter-year storage involves a decision to store grain from one year to the next. This can involve building additional grain storage, which might only be occasionally used by the producer.

Current rail freight rates are reported in Table 5. A C$30 fixed seaway shipping cost is added to east-moving freight rates. Freight rates for south movements to Minneapolis are obtained from Gray (1995) and inflated by 1% per year. Freight rates to the Pacific Northwest (PNW) include a $16/tonne per 160 kilometers trucking cost from Canadian origins to Minneapolis, and a $55/tonne rail freight for Minneapolis to PNW.[10]

Table 5: Freight Rates and Storage Cost Data

Region	Freight Rates ($)						One-Year Storage Cost ($)
	West Coast (Vancouver)	East Coast (Thunder Bay)	Seaway Shipping Cost	Total East Coast	South (Minneapolis)	South (PNW)	
AB	34	46	30	76	84	71	60
West SK	40	41	30	71	54	71	60
East SK	48	31	30	61	55	71	60
MB	51	25	30	55	41	71	60

Source: Authors' Calculations, Quorum Corporation (2015), Gray (1995).

RESULTS

Future Production

Table 6 presents the results of the AR estimation on grain production. All independent variables are statistically significant and have plausible signs. We use the Schwarz Criterion to select optimal lag length. An augmented Dickey-Fuller test is used to ensure that production time series are stationary. As mentioned, the dummy variables take into account exceptionally low production levels in 1988 and 2002, and exceptionally high production level in 2013.

The estimated coefficients for the lagged dependent variables show that production levels are positively and negatively correlated with their first and second lag, respectively. The estimated coefficients for the time trend variable show that, on average, production level across the three Canadian provinces has increased by 449,267 metric tonnes a year.

Table 6: Regression Results

Provinces:	Alberta, Saskatchewan, Manitoba	
Dependent Variable:	Aggregate Production	
Estimation Method:	VAR	
Independent Variables	Coefficient	Standard Error
Constant (β_0)	-8.50E+08	2.0E+08***
Aggregate Production (Lag 1) (β_1)	0.302	0.12**
Aggregate Production (Lag 2) (β_2)	-0.299	0.14**
Time Trend (β_3)	449,267	171,809***
Dummy for 1988 (β_4)	-10,434,793	4,435,866***
Dummy for 2002 (β_5)	-15,525,738	4,491,011***
Dummy for 2013 (β_6)	19,024,762	4,392,162***
R-squared	0.82	
Adjusted R-squared	0.78	
F-Statistic	21.46***	
Observations after adjustment:	36	

Source: Authors' estimation.

Note: Asterisks denote significance at the 5%(**), and 1%(***) levels.

Probability Density Functions

Using the results of the AR estimation and the PDF generation approach described in the methodology, future production is forecasted (see Table 7). Average grain production increases from approximately 55 MMT in 2016 to approximately 60 MMT in 2025 (see Table 7). The relevant probability distributions are similarly calculated from 2016 to 2025.

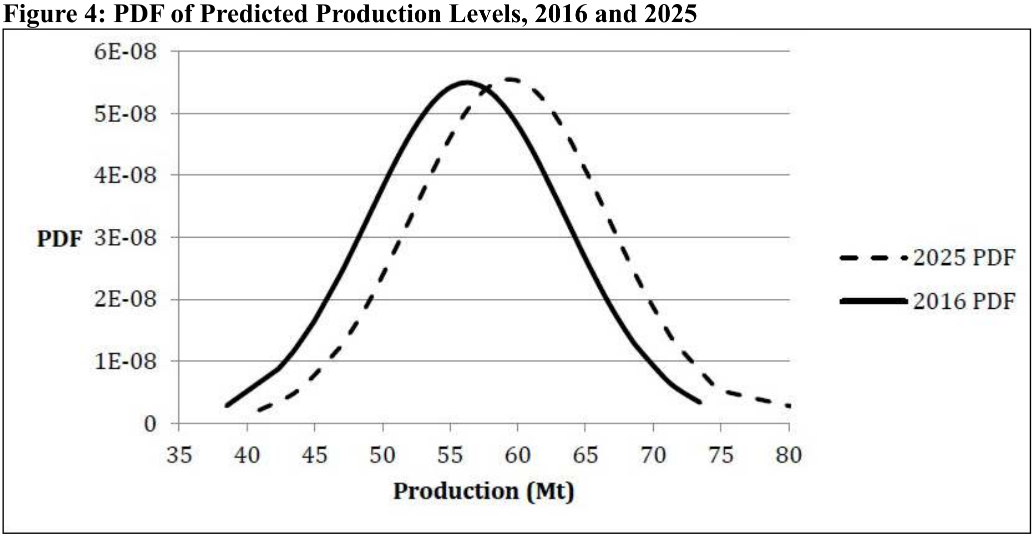
Table 7: Production Forecast

Year (t)	Mean ($\bar{Y}_t$) (tonne)	Standard Deviation (σ) (tonne)
2016	55,469,840	7,229,728
2017	55,919,107	7,229,728
2018	56,368,374	7,229,728
2019	56,817,641	7,229,728
2020	57,266,908	7,229,728
2021	57,716,175	7,229,728
2022	58,165,442	7,229,728
2023	58,614,709	7,229,728
2024	59,063,976	7,229,728
2025	59,513,243	7,229,728

Source: Authors' estimation.

As shown in Figure 4, the production probability distributions move to the right over time due to a systematic yield improvement of 449,267 tonnes a year.

Figure 4: PDF of Predicted Production Levels, 2016 and 2025



Source: Authors' estimation.

Expected Export Spread

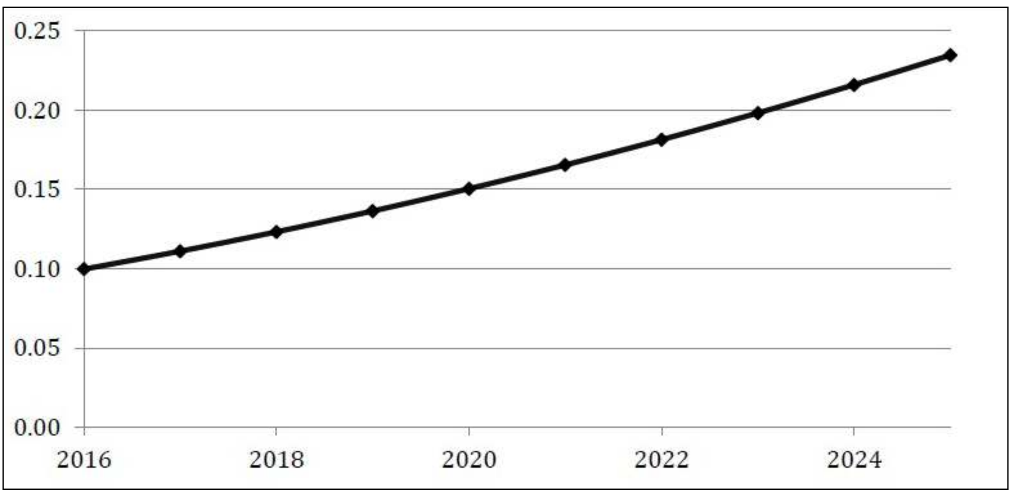
Table 8 shows the calculation of expected export spread levels for various production levels. Current rail capacity and domestic grain use add up to approximately 60 MMT, while an additional 4.75 MMT can be exported to the U.S. via trucking at a higher transportation cost. Therefore, we set expected export spread for production levels under 60 MMT equal to the normal export spread,[11] and production levels over 64.75 MMT must be stored for at least one year. Expected export spread for production levels over 64.75 MMT include expected storage cost.

Table 8: Expected Export Spread Calculations

Production Level	Expected Export Spread Level
0 to 60 MMT	Normal Export Spread
60 to 64.75 MMT	Freight to South
Over 64.75 MMT	Normal Export Spread + Expected Storage Cost

Since production levels increase over time, the probability of producing over the limit increases as well. This generates an increase in expected storage cost and, thereby, average expected export basis. Figure 5 illustrates the change in the probability that the region produces over 64.75 MMT of grain. This likelihood rises from 10% in 2016 to 23% in 2025.

Figure 5: Increase in Probability of Producing over Limit over Time



Source: Authors' estimation.

Expected export spread levels and rents are then calculated for a range of production levels in 2016 to 2025. Table 9 presents results for the last year forecasted, 2025. Expected export spread levels are calculated for each segment of the distribution. Recall that the average expected export spread is the weighted average of export spread levels reported for each segment, with weights the probabilities of production levels within each segment, as reported in column 2.

Critically, total expected export rents represent farmers' total potential future loss. This amount is effectively a transfer from farmers to grain companies. But some producers may be able to avoid the excess export spread by using forward-price and forward-contract deliveries. Also, if the limited export capacity causes insecure delivery schedules and consequently has a positive effect on FOB port prices, then a part of the total export rent is borne by international customers of Canadian grain.[12] So in 2025, the average expected export spread ranges from C$64 to C$81 per tonne for the three Canadian provinces (Table 9). We note that this amount is C$30 per tonne above normal and historical export basis, and implies expected export rents of over C$1.4 billion.

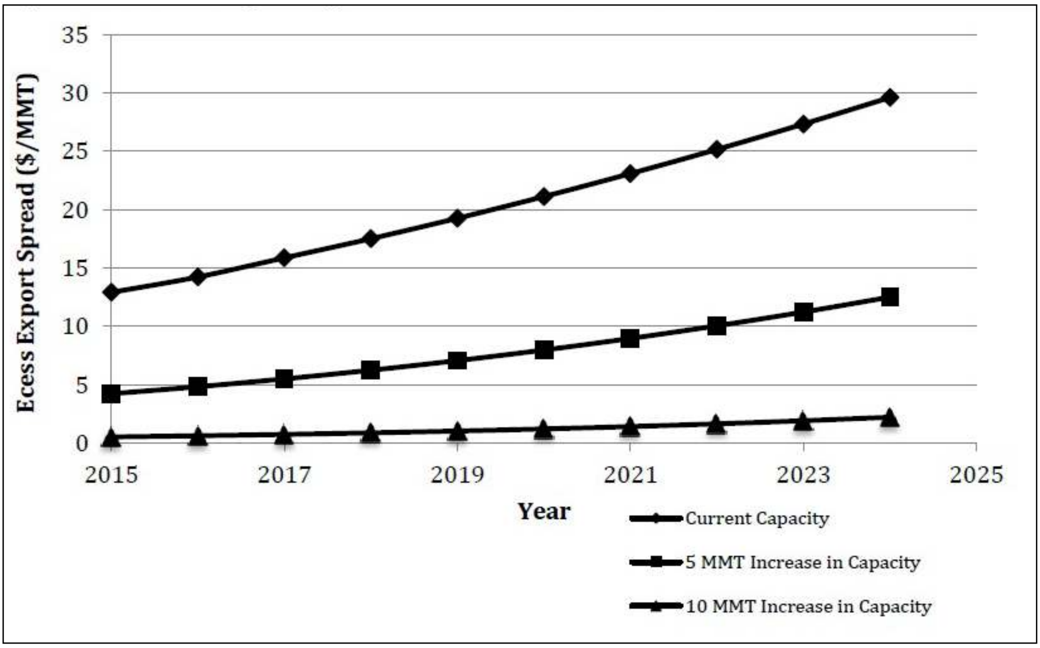
Table 9: Expected Export Spread in 2025

1	2	3	4	Expected Export Spread ($/tonne)			
Production Range (Y_t) (MMT)	Prob. of 1	Deliveries (MMT)	Prob. of over limit production next year	AB	West SK	East SK	MB
33-35	0.000	14	0.50	34	39	48	51
35-37	0.001	16	0.50	34	39	48	51
37-39	0.001	18	0.50	34	39	48	51
39-41	0.003	20	0.50	34	39	48	51
41-43	0.006	22	0.50	34	39	48	51
43-45	0.011	24	0.50	34	39	48	51
45-47	0.019	26	0.50	34	39	48	51
47-49	0.031	28	0.50	34	39	48	51
49-51	0.047	30	0.50	34	39	48	51
51-53	0.064	32	0.50	34	39	48	51
53-55	0.082	34	0.50	34	39	48	51
55-57	0.098	36	0.50	34	39	48	51
57-59	0.108	38	0.50	34	39	48	51
59-61	0.110	40	0.50	34	39	48	51
61-63	0.104	42	0.58	54	59	68	71
63-65	0.091	44	0.71	54	59	68	71
65-67	0.074	46	0.82	146	151	160	163
67-69	0.055	48	0.90	149	155	164	167
69-71	0.039	50	0.95	152	157	166	169
71-73	0.025	52	0.98	153	158	167	170
73-75	0.015	54	0.99	154	159	168	171
75-77	0.008	56	1.00	154	159	168	171
77-79	0.004	58	1.00	154	159	168	171
79-81	0.002	60	1.00	154	159	168	171
Average Expected Export Spread ($/tonne)				64	69	78	81
Average Excess Export Spread ($/tonne)				30	30	30	30
Expected Export Rents ($)	$1,432,574,902						

Source: Authors' estimation.

Figure 6 is a graphical representation of excess export spread levels under three hypothetical scenarios. Scenario 1 corresponds to the current rail situation and, subsequently, comprises a total capacity limit of 40 MMT. Scenarios 2 and 3 assume a 5 and a 10 MMT expansion in both rail and total GH&T system capacity, respectively. In fact, excess export spread levels fall significantly when export capacity is expanded. At current capacity levels, excess export spread reaches C$30/MMT by 2025. Contrast this with a 10 MMT capacity improvement by 2025. In this case, excess export spread remains under C$3/MMT.

Figure 6: Excess Export Spread Under Three Scenarios



Source: Authors' estimation.

Finally, Table 10 summarizes total expected export rents for the 2016-25 period under the three capacity scenarios. The net present value (NPV) of expected export rents under current export capacity is estimated to be over C$5.6 billion for the 10-year estimation period. Assuming 20% of the exportable supplies can avoid an above normal export spread through forward-pricing, forward-contracting, or movement south of the border, farmer losses from limited export capacity are still about C$4.5 billion. Note as well that expected export rents decrease by approximately C$3.4 billion when the export capacity is improved by 5 MMT, while a 10 MMT increase in export capacity generates a C$5.3 billion decrease in expected export rents.

Table 10: Expected Loss 2016-2025

	Expected Loss ($)		
Year	Scenario 1 (Current Capacity)	Scenario 2 (5 MMT Increase in Total Capacity)	Scenario 3 (10 MMT Increase in Total Capacity)
2016	612,253,621	213,360,937	29,251,864
2017	674,883,834	244,199,402	34,773,396
2018	755,710,573	278,618,174	41,204,065
2019	835,682,544	316,886,078	48,667,978
2020	921,265,020	359,269,105	57,298,871
2021	1,012,441,476	406,025,641	67,236,966
2022	1,109,284,116	457,397,255	78,643,497
2023	1,211,624,708	513,636,651	91,684,940
2024	1,319,436,821	574,936,653	106,525,055
2025	1,432,574,902	641,473,029	123,364,512
NPV*($)	5,642,797,981	2,239,295,615	368,928,292

* Net Present Value (NPV) is calculated assuming a 10% discount rate.
Source: Authors' estimation.

It is worth noting that this study does not explicitly take into account farmers' potential loss from the limited Canadian West Coast (i.e., Vancouver) port capacity. The Canadian west coast is a relatively less expensive export point for prairie grain, but the port is currently constrained to approximately 27 MMT (Quorum 2015). Exportable supply levels above 27 MMT must therefore be moved through other ports, but at a higher transportation cost. Future studies will need to quantify as well the cost to Canadian farmers stemming from increasingly insufficient West Coast export (port storage and handling) capacity.

CONCLUSIONS AND POLICY OPTIONS

We have highlighted that limited grain export capacity in Canada reduces western Canadian crop prices but at a substantial cost to grain growers and the regional economy, while creating opportunities for grain handlers and processors. The ex post analysis done to begin this analysis estimates Canadian prairie farmers' losses attributable to payments of excess export spreads in the 2013-14 and 2014-15 crop years to be at least C$5 billion. We offer that this is a significant transfer from farmers to grain handlers.

The ex ante analysis indicated that current production trends, without any improvements in grain export capacity, increase the future likelihood of capacity constrained grain markets in Canada. To this end, the NPV of expected congestion related export rents, losses primarily borne by farmers, is estimated to be C$5.6 billion over the next 10-year (2016-2025) period. Using these estimates, we also find that a 10 MMT increase in annual export capacity essentially eliminates these rents.

Export capacity improvement can be achieved through a variety of solutions. Increased rail capacity seems essential, but any expansion must be accompanied by an improvement in handling coordination, especially at the port grain terminals. We expect that congestion at grain export positions (i.e., Vancouver) and over supporting rail lines is another potentially important issue that the grain handling system will continue to face unless increases in rail capacity, port capacity, and handling coordination go hand in hand.[13]

Regarding transportation costs, the Canadian MRE policy on grain movement caps the average revenue per ton-mile of grain moved by the railways. This policy eliminates the ability to sell less rail service at higher freight rates, yet also gives the railways strong incentives to lower their costs per ton-mile and to move the volume offered to them (Nolan and Peterson 2015). But the MRE policy is imperfect to the extent that it provides very little incentive for railways to invest in additional capacity, to move grain during higher cost periods (winter), or to provide properly scheduled service. Additional research is needed to examine whether and how the MRE formula might be modernized to create incentives for the railways to increase their capacity.

Finally, more research is needed to examine practical solutions to increase competition in the western Canadian grain handling and transportation system. More competition in the grain supply chain is one way to help optimize existing and future capacity utilization in the Canadian grain handling system.

Endnotes

1. In 2014, a large U.S. grain crop was associated with similar problems in the PNW.

2. Other studies based in Canada, such as that of Gray (2015), have often used the term "export basis." This created some confusion among reviewers so we adopted this terminology.

3. As the largest volume port, we assume that Vancouver FOB minus the elevator bid prices are a representative measure of the export spread for grains in western Canada.

4. This differs from the grain transportation situation in the United States, where the railways capture most of the rents (i.e., from capacity constraints) by raising grain rates or auctioning off rail car shipments to the highest bidder.

5. See Richardson (1978).

6. These periods are used because Statistics Canada does surveys of farm stocks to provide more accurate estimates of farm sales during these intervals.

7. This paper performs an inter-year analysis of storage and shipment capacity rather than an inter-seasonal analysis. Canadian shipments from western Canada to the West Coast are distributed over all four seasons quite equally. In fact, July appears to be the only month of the year in which the system would generally have a short break before harvest. More information regarding the distribution of shipments can be found in Table 2B-1 of Quorum 2013-14 Annual Report (Quorum 2015).

8. Because expected capacity is significantly above expected production, the joint probability of storing three consecutive years became less than 1% of expected storage costs and therefore was incorporated into the simulation model.

9. Notably, when the basis spiked in February 2014, the dismal export performance to that date created expectations that the 2013 crop would create at least two years of larger carryover stocks (Gray 2015).

10. It is worth noting that there may have been other unlicensed shipments to the U.S. via trucking that could not be accurately measured and included in this study.

11. In this study, we define normal basis as the freight rate not including the handling cost.

12. Insecure delivery schedules may also result in demurrage payments made by grain companies to the international buyers. For more on demurrage costs in Canadian grain marketing, see Wilson and Dahl (2000).

13. Fan et al. (2012) investigated several aspects of such congestion in the U.S.

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