Transportation Shocks in the Pacific Northwest: Impact on Wheat Shipping Costs

Pacific Northwest Transportation Shocks

Simla Tokgoz[a], Christine Sauer[b,1], Claire Hutchins[c,1], Bryn Swearingen[d]

a Simla Tokgoz (corresponding author, simla.tokgoz@usda.gov) is a research agricultural economist at the U.S. Department of Agriculture, Economic Research Service.

b Christine Sauer is a former research agricultural economist at the U.S. Department of Agriculture, Economic Research Service.

c Claire Hutchins is a former agricultural economist at the U.S. Department of Agriculture, Economic Research Service.

d Bryn Swearingen is an agricultural economist at the U.S. Department of Agriculture, Economic Research Service

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Abstract

The Pacific Northwest, an important export hub for wheat grown in the Pacific Northwest and Northern Plains, is connected by a transportation network of barge, rail, and truck. One policy consideration is the removal of four Lower Snake River locks and dams in response to environmental concerns. To analyze this, we use a spatial optimization model for wheat transportation. We find that, depending on several factors - the magnitude of the shock, changes in wheat prices, shipping utilization by producers, rail company behavior for shipping costs, and export demand response - total landing costs increase from 2.30% to 12.00%.

Keywords: barge, Pacific Northwest, rail, shipping costs, wheat

1. Introduction

Transportation networks play an important role in agricultural markets by connecting farmers to global markets (Washington Governor's Office, 2022; WSDOT, 2024).

The Pacific Northwest (PNW)[1] is an important hub for U.S. wheat exports, especially for wheat produced in the PNW and Northern Plains. Most wheat grown in the PNW for export is transported by barge to export terminals, with the Columbia and Snake Rivers serving as a thoroughfare for these shipments. Together, the Columbia and Snake Rivers form the Columbia Snake River system (CSR), on which barges move about a third of all the wheat exported from ocean ports (Supplementary Material Table A.2). Figure A.1 in Supplementary Material A shows the Columbia-Snake Inland Waterway, with its eight locks and dam pairs. In addition, wheat produced in other states such as North Dakota, Montana, and Kansas for export out of PNW ports travels to these terminals by rail (Jaller, 2022).

The PNW wheat supply chain includes three transport modes: barge, rail, and truck. Generally, wheat is transported by truck to a rail or a barge elevator and then shipped to port terminals in Portland (the majority) or Seattle (USDA FAS, 2025). This network is highly interconnected, and shocks such as lock closures have impacted shippers' choice of mode, volume of wheat moved, shipment routes, costs of transportation, and storage choices (Jessup and Casavant, 2005; USDA AMS, 2010; Burton, 2019; USACE, 2020). Wilson and Klebe (2024) identify various factors causing disruptions in grain supply chains such as volatility in demand, increased fuel costs, labor shortages, port and interior logistical congestion, changes in global shipping patterns, and port restrictions. Furthermore, transportation costs impact all attributes of the wheat shipment. Johnson and Wilson (1993) find that wheat cleaning before

[1] In this study, PNW refers to Washington (WA), Oregon (OR), and Idaho (ID).

shipment increases with higher transportation costs due to higher implied savings on freight costs. In this context, any shock to the transportation system warrants careful analysis.

One potential source of future disruptions is the contemplated removal of four lower Snake River[2] locks and dams—Lower Granite, Little Goose, Lower Monumental, and Ice Harbor (Figure A.1) — in response to environmental concerns around the restoration of native fish habitats in the Columbia River Basin. The States of Washington and Oregon, as well as four tribal organizations, have indicated support for removing the dams, and in 2023 the White House issued a memorandum establishing an intent to work with Congress, tribal nations, states, and other stakeholders to pursue solutions to the issue (CBRI, 2023; The White House, 2023). In 2025, the White House issued a Presidential Memorandum revoking this agreement, which led to USACE and Bureau of Reclamation to withdraw the "Notice of Intent to Prepare a Supplemental Environmental Impact Statement for the Columbia River System Operations" (Federal Register, 2025). Supporters of dam removal suggest that barge shipments could be diverted to rail and truck transport by upgrading rail infrastructure and improving state and local roadways (CBRI 2023). Since barge transportation is generally recognized as the most cost-effective mode of long-distance freight transportation (WSDOT, 2024), the potential effects of the suggested dam removal on the regional and national agricultural economies could be substantial. Additionally, because barges can haul much greater volumes than alternatives such as shuttle trains or trucks, the costs of moving barge freight to an alternative mode of transportation could be substantial (Fruin, 1995).

This study attempts to determine the effects on transportation flows and costs in the PNW of potential disruptions in barge transportation. We consider two scenarios: elimination of barge

[2] The Lower Snake River includes the portion of the Snake River between Lewiston, ID, and the Columbia River (WSDOT, 2024).

shipments along the CSR, and elimination of barge shipments in the Snake River. Since the proposed removal of the four dams is under serious consideration, this study asks "What would result from eliminating a transport mode (e.g. barge) in the PNW?" The study assesses the possible economic impact of such an event on the PNW and Northern Plains transport system, while accounting for the interconnectedness of different transport modes and their relative costs. Therefore, first a transportation simulation model for wheat in the PNW and Northern Plains is built to analyze the impacts of shocks on transport costs, choice of transportation mode, and volume of wheat delivered from each supply location. The model includes three transportation modes (barge, rail, and truck) moving wheat from various supply locations to two export ports.

The transportation model is formulated as a spatial optimization model and uses linear programming to find the lowest landing cost (transportation cost plus wheat price) alternative to transport wheat from multiple supply locations to multiple demand locations on an annual basis. It solves for the optimal flow of wheat from each supply location to each demand location that would meet export demand. The linear programming setup answers two questions: "What are the optimal quantities that should be shipped between each supply and each demand location?" and "What is the total landing cost for shipping those quantities?".

Three features of the model differentiate this study from previous ones. First, landing costs for wheat are used in the optimization problem to consider the effects of a shock on the different wheat classes produced in these regions with associated segmented export demand markets since wheat prices may vary by wheat classes. At the same time, wheat classes differ by production location, and wheat is not easily substitutable across classes for either domestic or export markets. Wilson (1989) notes that the price of wheat in international markets reflects quality characteristics, such as protein level, spring versus winter, color, and country of origin. Thus,

including wheat prices allows differentiation of wheat in various domestic and international markets into our model.

Second, our analysis requires that export demand for each class of wheat is met, rather than subsuming those different commodities into one general commodity, wheat. Third, the model incorporates all rail-delivered wheat to Portland and Seattle ports, including from the supply regions of the Northern Plains as well as the PNW. Thus, includes the impact of a barge shock on rail shipments from regions in addition to the PNW. Although previous studies have analyzed the impact of removal of four dams and locks in the Lower Snake River, they did not consider in detail the role of wheat prices differentiated by class and production locations in shipment choices, and they did not consider the impact on rail shipments from the Northern Plains to PNW ports.

This study may provide insights to policymakers who seek to develop a strategy that directly supports agricultural supply chains in the PNW. The Washington Governor's Office (2022) summarizes the range of services and associated benefits currently provided by the four dams and describes actions that have been considered if the dams were to be removed, along with expected results of replacement actions and anticipated costs. A study by FCS Group (2020) on the potential transportation and economic impacts of removing the Lower Snake River dams and closing the four locks estimate the national transportation-related impacts at $2.23 billion (net present value). FCS Group conducted 14 expert interviews where interviewees projected that without Snake River navigation, their transportation/storage costs would increase by $0.20-$0.40 per bushel (a 50%-100% increase).

A USACE (2020) constrained-optimization model estimates that eliminating Snake River navigation would raise wheat transport costs by $0.07-$0.24 per bushel, adding $13-$48 million

in total wheat shipping costs annually. Removing the four dams would affect transport of 2.1 million metric tons (mmt) of wheat. With rail rates unchanged, total rail-barge costs would rise 9.6% to $158.8 million; if rail rates climb 25% (50%), costs would increase 21.6% (32.9%) to $176.15 ($192.65) million. USACE uses a transportation model to optimize transportation costs. It offers landing-cost examples based on a single regional wheat price, but omits spatially differentiated prices and flows beyond the Columbia-Snake basin, i.e. shipments from the Northern Plains.

Jaller (2022) evaluates dam removal with county-level production and infrastructure data, assuming wheat was routed to the lowest-cost ocean port. Rail volume rises from 1.5 mmt to 2.9 mmt, while barge traffic falls from 3.8 mmt to 2.3 mmt. Total transport cost rises 14% ($0.11 per bushel). Although Jaller captures detailed regional networks, the analysis excludes Northern Plains origins, confining additional rail pressure to the Pacific Northwest and understating the full impact of barge loss. It also minimizes only transport costs, ignoring wheat prices that may differ by class and location.

This paper is organized as follows. We first discuss the wheat transportation system in the PNW and its characteristics. We follow by presenting the transportation model. Then, we present our Baseline and Scenario Analyses and discuss empirical results. Sensitivity analyses of scenario results follow, after which we provide some concluding observations.

2. Wheat Transportation System in the PNW

The PNW is a dominant port for wheat exports since it is near significant wheat production and an important export gateway for shipments to Asia (Jessup and Casavant, 2017). Between 2012 and 2023, annual wheat exports from Portland and Seattle ports combined ranged from 9.5 mmt to 15.3 mmt, making up an annual average of 50% of total U.S. wheat exports (USDA FAS,

2025). Due to this importance, there have been significant investments over the years, with total investment in export elevator capacity exceeding $1 to $2 billion (Jessup and Casavant, 2017).

Many rail investments in the PNW have increased capacity, particularly those made by BNSF Railway in Washington State (Ibid.). Grain shippers in inland PNW have also made significant investments in transportation capacity over the years, adding shuttle rail loading capabilities at several locations in Eastern Washington. The combined investments in transportation capacity from export elevators, railroads, and grain shippers have significantly improved the grain supply chain and increased the export competitiveness of grain shippers in the PNW and Upper Midwest [Ibid.].

Cargo transported in the Columbia Snake River navigation system starts at the Snake River near Lewiston, ID and Clarkson, WA to the Snake River confluence with the Columbia River near Pasco, WA. It continues on the Columbia River to its confluence with the Pacific Ocean near Astoria, OR (USACE, 2020). The seven Washington counties heavily reliant on the Snake River are Adams, Asotin, Columbia, Franklin, Garfield, Walla Walla, and Whitman (WSDOT, 2024).

Wheat, barley, and rye downbound movements on the Columbia River between Portland/Vancouver and The Dalles from 2015-2019 averaged 4.4 mmt per year. For the Snake River, this volume was 2.4 mmt. Grains alone account for over 84% of all tonnage moving on the Snake River upriver of Ice Harbor Dam. Most volumes arriving at river port barge facilities and shuttle rail facilities left the farm via truck. Non-shuttle rail also serves as an intermediary between the farm and river ports and between the farm and shuttle rail facilities. The presence of a multi-modal transportation system plays a very important role in the development of on-farm or commercial storage and facilities investment for efficient movement of crops from the field to

the consumer's table (Jessup and Casavant, 2005).

The Washington Governor's Office (2022) notes that the four Snake River dams provide more than 100 miles of river navigation and transportation between Lewiston, Idaho and the Tri-Cities, Washington. Removing dams would eliminate all commodity barge shipments between the Tri-Cities and Lewiston-Clarkston, causing that transportation to shift to regional rail and trucking. Many studies estimate that rail would become the dominant regional transportation mode, followed by trucking (Ibid.). This would require significant improvements to expand and upgrade short-line rail networks and roadways.

Given this highly interconnected system, long- or short-term shocks could reverberate across all transportation modes. Recent shocks to the PNW and U.S. grains transportation system illustrate its fragility. In September 2019, a lock closure on the Bonneville dam in the CSR system impacted barge shipping through delays, and was reflected in basis values approximately 38% higher than the annual average surrounding this period (USDA AMS, 2026b). In September 2022, disputes between major railroads and their employees came to a head as rail unions threatened to strike, which led to increases in secondary rail car market premiums after a long period of zero or negative discounts (USDA AMS, 2026a).

Jessup and Casavant (2005) present results from a survey on transportation modes in Eastern Washington; more than 83% of responding houses used truck–barge. The next two most-used modal choices were truck only and bulk rail. When they compare transportation rates, they find that the closer a county is to the river system, the greater the differential between rail rates for 1-25 cars and 26-109 cars, suggesting that truck-barge rates create downward pressure on bulk rail rates. Train and Wilson (2006) estimate transportation elasticities in the Columbia Snake River basin using survey data from Jessup and Casavant (2005). Survey results based on revealed-

choice data identify six routes for shippers. About one-third (32.7%) of shippers choose the "Truck to Port, Barge to Portland" option, followed by "Rail to Portland" (16.1%), "Truck to Rail, Rail to Portland" (13.7%), "Barge to Portland, Without Truck Access to Barge" (8.3%), and "Truck to Pasco, Barge to Portland" (7.3%). Nearly half (48.3%) of the shippers indicated that they would select an option involving a barge, showing the dominance of this shipping mode.

3. Transportation Model

This paper's transportation model for wheat addresses two questions: "What are the optimal quantities that should be shipped between each supply and demand location so as to minimize total landing cost?" and "What is the total landing cost for those shipments?" We assume that the export demand for U.S. wheat is met and do not include domestic demand since it is stable over time. Thus, the model includes constraints such that export demand is met and supply does not need to be exhausted. To find the least cost combination of routes, the model is set up as a spatial optimization model. In a simulation with a shock, the model shows the change in total landing cost (including all modes and all routes), and the change in shipments flowing along each route.

The model includes all three transportation modes across the PNW and Northern Plains. Transport costs are defined as a) truck cost (from farmgate to elevator) plus rail cost from elevator to the port, and b) truck cost (from farmgate to elevator) plus barge cost from elevator to the port. Transport costs are combined with relevant wheat prices to compute landing costs for each route (Supplementary Material Table A.8 and Table A9).

Input data for each calendar year include transportation costs and wheat prices that differ spatially from each supply location to each demand location and by mode (rail, barge) expressed in $ per metric ton ($/mt). Truck costs also vary based on regional characteristics of each supply location, for either short-haul or long-haul distances to the rail or barge elevators.

Export demand locations are two ports: Portland and Seattle (Figure A.2). Wheat export data for these two ports are based on Bureau of Economic Analysis (BEA) regional definitions: Portland-Salem, OR-WA, and Seattle-Tacoma-Bremerton, WA (BEA, 1995). The model has 25 supply locations (based on BEA regions) from Surface Transportation Board's (STB) Waybill dataset (STB, 2026) (Table A.1). Input data are for the 2017–2021 period.

In the model index s represents supply locations for rail and barge shipments. Index d represents market locations for demand: export demand from Portland and export demand from Seattle ports. The available supply of wheat in location s is a_s, export demand at location d is b_d, and volume of wheat shipped from supply location s to demand location d is x_{sd}.

An important feature of this model is its use of spatially differentiated wheat price data for each rail region and for barge. U.S. wheat production is regionally diversified: Washington, Oregon, and Idaho produce soft white wheat, while the Northern Plains states produce hard red winter, hard red spring, and durum (Figure A.3). Thus, transportation routes reflect differentiated wheat classes in addition to production locations. Further, different wheat classes may have different export destinations. Soft white wheat is usually barged to the Portland port (USACE, 2020). Other classes of wheat are usually railed to PNW ports (USDA AMS, 2010). Since wheat class also differs by location, rather than using transportation costs, the model uses "landing costs" (lc), which are defined as follows:

$$lc_{sd} = tc_{sd}^{rail} + sec_s + tc_s^{truck} + price_s^{wheat} \quad (1)$$

$$lc_{sd} = tc_{sd}^{barge} + tc_s^{truck} + price_s^{soft\ white\ wheat} \quad (2)$$

where tc_{sd}^{rail} is rail cost for each route to each port, tc_{sd}^{barge} is Columbia Snake River barge cost to the port, sec_s denotes a secondary rail car market discount/premium for rail shipping from supply location s, tc_s^{truck} is truck cost from farmgate to elevator, and $price_s^{wheat}$ is the price of

wheat from supply location s. Next, we define total landing cost z as $\sum_s \sum_d tc_{sd} \cdot x_{sd}$, expressed in $. We do not consider the possibility of barge shipments switching to truck since trucking is not considered a substitute for long-distance rail or barge shipping, because of the current shortage of truck drivers and trucks in this region, and because of higher trucking costs relative to barge and rail for long-haul distances (Ndembe and Bitzan, 2022; WSDOT, 2024).[3]

Since wheat classes may not be interchangeable in export markets, the model considers these segmented wheat markets and their demand by including a constraint so that WA-OR-ID[4] shipments (predominantly soft white wheat), rail plus barge, exceed a specified amount. This constraint implies that the rest of the wheat export demand will be met by shipments from Northern Plains supply locations (hard red spring, hard red winter, and durum). In this model specification, all supply routes respond to export demand, but each supply market supplies a minimum volume of wheat.

Also, lower bounds for all individual shipment routes are imposed, since farmers in these regions produce wheat and there would always be some volume of shipment since not all wheat can go to storage.[5] We write the theoretical model as:

Minimize objective function (total landing cost) $z = \sum_s \sum_d lc_{sd} \cdot x_{sd}$ (3)

Observe supply limit at regions s: $\sum_d x_{sd} \leq a_s$ for all s (4)

Satisfy export demand at markets d: $\sum_s x_{sd} \geq b_d$ for all d (5)

$x_{sd} \geq (minimum\ shipment\ volume)$ for all s and d (6)

$\sum_{WA-OR-ID} x_{sd} \geq \sum_{WA-OR-ID} minimum\ shipment\ volume_{s,d}$ (7)

[3] Tables A.4, A.5, A.6, A.7 and the Data Description section in Supplementary Material A provide the detailed transportation costs.
[4] These supply regions are Spokane WA-ID, Idaho Falls ID-WY, Twin Falls ID, Richland-Kennewick-Pasco WA, Casper WY-ID-UT, Portland-Salem, OR-WA, and Redding, CA-OR, all of which ship to Portland and Salem.
[5] The value of the objective function across different lower bound values differed less than 1%.

Input data sources for model parameters and variables are provided in Supplementary Material Table A.3.

4. Baseline and Scenario Analyses

4.1 Baseline

For the Baseline, the model uses the maximum available supply between 2017 and 2021 as input data for a_s to reflect a realistic measure of full railroad and barge capacity. Landing costs (lc_{sd}) are the average between 2017 and 2021 to reduce market volatility in transportation costs and wheat prices. Demand in the two export markets (b_d) is the average demand between 2017 and 2021 for each, to remove volatility from demand and to consider long-run demand potential. Using average lc_{sd} and b_d, and combining with maximum available supply a_s expand the supply frontier to consider all production areas, allows the model to evaluate impacts of a large shock, and illustrates long-run results for transportation shock. We impose a lower bound on shipments from each production region to each demand location (x_{sd}). For the Baseline, the lower bound is the minimum volume shipped in the study period divided by five.[6]

To consider the segmented wheat export markets, we add a constraint for WA-OR-ID shipments (rail plus barge) to exceed a specified volume, which is the sum of minimum shipments in the input data from barge, WA rail, OR rail, and ID rail:5.14 million metric tons (mmt). State level aggregates for shipment volumes of wheat are provided in Figure 1 through Figure 8, on the left side. Table B.2 and Table B.3 in Supplementary Material B provide optimal shipment volume for each supply location in the Baseline solution, and the range of shipment volumes for the data used in the study (2017-2021). In the Baseline, landing costs total $4,278 million. The optimal barge volume shipped in the Baseline is 4.62 mmt at a landing cost of

[6] We choose this lower bound since it gives the lowest total landing cost among all tried lower bound assumptions.

$276.29 per mt. The optimal rail volume shipped is 9.3 mmt.

4.2 Removal of Barge Option on the CSR System

In Scenario 1A, we remove the barge option for shippers, so that only rail transportation is available in the PNW and Northern Plains to meet export demand. In this scenario, we allow all supply regions to respond to the shock to consider the long-run impacts of barge removal on all rail deliveries, including rail shipments from outside the WA-OR-ID region. For rail supply regions to meet the export demand of 13.92 mmt (13.77 mmt in Portland and 0.15 mmt in Seattle), we allow total rail capacity to increase to handle the volume previously shipped by barge.[7] Thus, the maximum available supply of rail transportation for all regions expands by 38%, ignoring the effect of any change in transportation costs or wheat prices. This scenario allows infrastructure adjustments to expand rail capacity in the PNW and Northern Plains, and transportation costs to remain at long-run average levels. Since it is unlikely that importers will substitute for other classes of wheat, and since each class tends to be grown in a particular region, we impose that the wheat shipments of WA-OR-ID by rail must be equal to or exceed a certain volume, specified here as the available supply of this region by rail (2.34 mmt).

Table 1 summarizes assumptions and results for the Baseline and Scenario 1A. Figure 1 presents the optimal shipment volumes at state levels in the Baseline and in Scenario 1A, in which the North Dakota, Washington, and Montana supply regions respond the most. Detailed scenario results are presented in Table B.4 and Table B.5. In this scenario, total landing costs in the system increases by 6.62% to $4,561 million.

In Scenario 1B, we consider a narrower regional response to the barge shock and let only the PNW rail supply regions respond; i.e. this scenario allows regional rail shipments only in WA-

[7] USACE (2020) writes that as the industry adapts over time, more rail capacity and linked storage would likely be added in the region to accommodate freight affected by loss of river navigation on the Lower Snake River.

OR-ID to respond to the elimination of 4.62 mmt of barge transportation. This scenario considers the short-run impact of barge removal only in the surrounding region of CSR system. For PNW rail supply regions to meet the export demand of 13.92 mmt, we allow total rail capacity in these states to increase to replace the capacity lost by barge removal. Thus, the maximum available supply for PNW region needs to expand by 272% ignoring the effect of any change in transportation costs or wheat prices. Since shipment volumes for *ND, MT, SD, IL,* and *NE* are set to Baseline shipment volume levels, the WA-OR-ID region rail supply availability must expand more to meet the export demand. Thus, this scenario shows the results when infrastructure adjustments are made to expand PNW rail capacity assuming transportation costs remain at long-term average levels.

Rail shipments of the regional system for WA-OR-ID for wheat meet the constraint in equation (4) – shipments not exceeding 6.31 mmt. Table 1 summarizes assumptions and results for the Baseline and Scenario 1B; detailed scenario results are presented in Table B.6 and Table B.7. In this scenario, total landing cost in the system increases by 8.71% to $4,650 million. Figure 2 illustrates that supply regions in Washington respond the most to the barge removal shock.

4.3 Removal of Barge Option on Select Portions of the CSR System

In Scenario 2A, barge availability is limited to the Columbia River portion of the CSR system (i.e., we remove the barge option from Snake River ports as supported by the States of Washington and Oregon, as well as four tribal organizations). The model allows all rail supply regions throughout the PNW and Northern Plains to respond. While the barge volume in the Baseline is 4.62 mmt at a landing cost of $276.29 per mt, the barge volume in Scenario 2A is 1.83 mmt (a 60% decline) at a landing cost of $276.29 per mt. For rail supply regions to meet the

export demand of 13.92 mmt, we allow total rail capacity to increase to meet the volume lost from barge reduction. Thus, the maximum available rail supply for all regions expands by 24%, assuming no change in transportation costs or wheat prices. This scenario shows the results when infrastructure adjustments are made to expand PNW and Northern Plains rail capacity and transportation costs remain at long-term levels.

Because importers are unlikely to switch to different wheat classes, and because each class is typically grown in a specific region, we require that rail shipments of wheat from WA-OR-ID meet or exceed a minimum volume. This minimum is set at the region's available rail supply of 3.94 mmt. Table 2 summarizes the Baseline and Scenario 2A; detailed scenario results are presented in Supplementary Material B Table B.8 and Table B.9. Figure 3 presents how shipment volumes change for all rail supply regions and barge in Scenario 2A relative to Baseline, where Washington and North Dakota rail regions respond the most. In this scenario, total landing cost in the system increases by 4.35% to $4,463 million.

In Scenario 2B, we limit barge availability to only the Columbia River portion of the CSR system, which reduces barge availability by 2.79 mmt, and let only rail supply regions in the PNW respond to the 2.79 mmt reduction in barge availability. For PNW rail supply regions to meet the export demand of 13.92 mmt, we allow total rail supply in these states to increase to meet the additional volume from barge reduction. Thus, maximum available rail supply for all regions expands by 175% without any change in transportation costs or wheat prices. This scenario shows the results when infrastructure adjustments are made to expand PNW rail capacity and transportation costs remain at long-term levels. Shipment volumes for *ND, MT, SD, IL,* and *NE* are set to Baseline shipment volume levels. Shipments of regional system for WA-OR-ID for wheat for rail meet the constraint in equation (4) at 6.17 mmt. Table 2 summarizes

Baseline and Scenario 2B, whereas detailed scenario results are presented in Supplementary Material B Table B.10 and Table B.11. In this scenario, total landing cost in the system increases by 5.25% to $4,502 million. Figure 4 illustrates that rail supply regions in Washington respond the most to this shock.

5. Sensitivity Analyses

5.1 Higher Rail Costs

With a large shock such as the removal of the barge option from the transportation network, it is quite plausible that rail delivery costs would increase due to the investment in infrastructure that such a change would necessitate.[8] WSDOT (2024) suggests that removal of the barge option would spur an increase in rail rates since barge availability provides a cap on rail rates. So, we conduct a scenario analysis of CSR system shock with higher rail costs. In this scenario, the rail costs of each route increase by 25%, while secondary market premiums, truck costs, and wheat prices remain the same. The 25% increase in rail costs is based on a scenario presented in USACE (2020). The results for this scenario 3A (Table 3) show that total landing costs would rise to $4,699 million, a 9.87% increase from the Baseline. Results for scenario 3B with a CSR system shock but only WA-OR-ID responding (Table 3) show total landing costs of $4,768 million, an 11.47% increase from the Baseline. Detailed results for these scenarios are presented in Supplementary Material C Table C.1, Table C.2, Table C.3, and Table C.4. Figures 5 and 6 illustrate the state-level responses of wheat shipments in these scenarios.

5.2 Export Demand Response

As seen in Scenarios 1A and 1B, total landing costs increase in response to a shock in the

[8] Wilson (2019) shows that historical rail rates for wheat increased over time. He finds that shipment distance, shipment size, railroad competition, and barge competition negatively affected wheat rail rates, whereas fuel prices, interchanges, and distance to water from origin had positive impacts.

transportation system from removing barge as an alternative transportation mode. The higher costs might lead some buyers to switch to alternative supply sources. Reimer, Zheng, Gehlhar (2012) estimate the price elasticity of export demand for U.S. wheat as -1.25, where price is defined as the U.S. internal price. Considering that total landing costs increased by 6.62% in Scenario 1A, we decrease the export quantity demanded by 8.28% ($1.25 \cdot 6.62\%$) in response to the barge removal in CSR system. In this scenario (4A), where not only transportation options are reduced, but also export quantity demanded decreases, we see that total landing costs decrease by 2.30% to $4,179 million, since the quantity demanded decline of 1.15 mmt decreases total transportation demand (Table 4). Detailed Scenario results are provided in Supplementary Material C Table C.5 and Table C.6. Figure 7 illustrates that rail supply regions in North Dakota, Montana, and Washington respond the most.

5.3 Wheat Supply and Price Response

The wheat price used in the scenarios is based on historical averages, to reflect long-run. However, significant changes in transportation costs may affect the net income of the origin, thereby influencing farmers' production decisions and equilibrium prices. To consider this possibility, we increase the wheat price in Scenario 1A. Valenti et al. (2026) analyze the impact of supply and demand shocks on global wheat markets using Bayesian structural vector autoregression models. They find that wheat supply disruptions decrease wheat production by 5.3%, increasing wheat price by 5.9% on average. We use this price increase as a benchmark since wheat production and wheat prices are not endogenous in our model. In Scenario 5A, we remove the barge option on the CSR system and increase the wheat price by 5.9% at the same time. Total landing costs increase by 12% to $4,791 million (Table 4). Detailed scenario results are provided in Supplementary Material C Table C.7 and Table C.8. Figure 8 presents the change

in shipment volumes in this scenario.

6. Conclusions

The Pacific Northwest (PNW) is an important export hub for wheat grown in the PNW and Northern Plains. The Columbia and the Snake Rivers serve as a thoroughfare for barge shipments of wheat grown in WA-OR-ID regions to Asian export markets, while rail carries wheat grown in the Northern Plains to export ports in the PNW region. An interconnected transport network is used to move wheat from farms to distant markets abroad. Thus, an economic or policy shock would impact shippers' choice of mode, volume of wheat moved, shipment routes used, and transportation costs.

One specific possibility is the proposed removal of four Lower Snake River locks and dams in response to environmental concerns around the restoration of native fish habitats in the Columbia River Basin. Such a change would make farmers and shippers more captive to the remaining transportation alternatives, affecting the flow of wheat from producers to consumers. Since barge transport is relatively cheaper than rail and is used extensively by farmers in the WA-OR-ID region, the dam removal could have significant impacts on the regional and national agricultural economies.

To analyze this policy consideration, we use a regional wheat transportation model that includes the complete PNW and Northern Plains wheat supply regions, and thus providing a long-run perspective on a shock’s impact. Since removal of locks and dams would be a significant change in the transportation network, we need to consider long-term responses. Moreover, wheat classes differ by production location, and wheat of one class is not easily substitutable for other classes for either domestic or export markets. A second contribution of this analysis is requiring that export demand for each class of wheat is met, rather than

subsuming those different commodities into one commodity "wheat". Including wheat prices in the model allows us to consider alternative wheat classes, since prices vary by class in addition to by production location. Wilson (1989) showed that wheat market also includes quality-related price differentials. Thus, incorporating this characteristic into our analysis through wheat prices allows us a more in-depth analysis of U.S. competitiveness in international markets when transportation shocks occur. In sum, this research bridges multiple key gaps in the literature by incorporating the spatial production allocation of different wheat classes and their respective prices.

We utilize this model for several scenarios that include elimination and partial elimination of barge transportation. We find that if all barge shipment options are eliminated, total landing cost increase between 6.62% and 11.47%, depending on which rail regions respond fully and the response of rail companies through their shipping costs. If export quantity demanded decreases in response to higher landing cost of wheat from the U.S., total landing cost may decrease by 2.30%. If transportation shock leads to higher wheat prices, then total landing cost is estimated to increase by 12%. If the barge shipment option is reduced to only the Columbia River portion of the CSR, we find that total landing cost increases between 4.35% and 5.25%. We present a detailed comparison of our study's results to previous studies in Supplementary Material B Table B.1 illustrating that there is a range for impact on transportation and landing costs depending on how rail capacity, rail shipping costs, and shippers respond.

However, the study results come with caveats. Although Wilson and Klebe (2024) find that grain inventories are part of an optimal purchasing strategy for shippers due to various uncertainties, our model does not account for inventories since the detailed data needed to map capacities and inventory costs to BEA regions were not available. Incorporating inventory

options would influence how much shippers are willing to pay in the secondary railcar market, since the shippers could choose to hold inventories rather than ship based on relative costs. Consequently, this would influence both overall rail shipping expenses and their short-term cost ratio relative to barge shipments. Since some of our scenarios incorporate long-run dynamics, we are confident that our analysis adequately addresses this caveat.

Another limitation is that we assume that rail transportation would be able to absorb the volume of new shipments through infrastructure investments. However, the extent to which rail could absorb increased volumes would also depend on the availability of rail crews and rail equipment and the ability of grain export terminals to handle increased rail traffic. By conducting a sensitivity analysis that incorporates higher rail shipping costs that would finance this capacity expansion, we believe this caveat is also addressed. One final point is that the model in this study assumes that shippers minimize total landing cost given shipping rates. Other factors, such as quality of service, may also play a role in shipping choices, as Ndembe and Bitzan (2022), Holguín-Veras et al. (2021), and Ben-Akiva et al. (2008) have demonstrated.

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Table 1. Summary of Baseline and Scenarios using landing costs with CSR system shock

Model	Baseline	Scenario 1A (remove barge, PNW and Northern Plains rail responds)	Scenario 1B (remove barge, PNW rail responds)
Model type	Complete PNW and NP markets respond (segmented markets)	Complete PNW and NP markets respond (segmented markets)	Only WA-OR-ID regions respond; remaining regions are set to baseline solution (segmented markets)
Transportation costs	Long-run average	Long-run average	Long-run average
Wheat Price	Long-run average	Long-run average	Long-run average
Export demand	Long-run average	Long-run average	Long-run average
Supply	All supply regions ship based on maximum supply availability	All supply regions ship based on maximum supply availability	Casper, Spokane, Idaho Falls, Twin Falls, Richland-Kennewick-Pasco, Redding, Portland-Salem expand based on maximum supply availability
Constraints	Shipments of regional system for WA-OR-ID for rail and barge ≥ sum of minimum shipments to Seattle and Portland from that region (≥5.14 mmt)	Shipments of regional system for WA-OR-ID for rail ≥ sum of maximum supply in scenario to Seattle and Portland (≥2.34 mmt)	Shipments of regional system for WA-OR-ID for rail is ≤ sum of maximum supply in scenario to Seattle and Portland (≤6.31 mmt)
Regional shipments	WA-OR-ID ships a minimum amount	WA-OR-ID ships a minimum amount in response to shock	Only WA-OR-ID ships in response to shock
Total landing cost	$4,278 million	$4,561 million (6.62% increase)	$4,650 million (8.71% increase)

Table 2. Summary of Baseline and Scenarios using landing costs with Snake River shock

Model	Baseline	Scenario 2A (remove barge from Snake River, PNW and Northern Plains rail responds)	Scenario 2B (remove barge from Snake River, PNW rail responds)
Model type	Complete PNW and NP markets respond (segmented markets)	Complete PNW and NP markets respond (segmented markets)	Only WA-OR-ID regions respond; remaining regions are set to baseline solution (segmented markets)
Transportation costs	Long-run average	Long-run average	Long-run average
Wheat Price	Long-run average	Long-run average	Long-run average
Export demand	Long-run average	Long-run average	Long-run average
Supply	All supply regions ship based on maximum supply availability	All supply regions ship based on maximum supply availability	Casper, Spokane, Idaho Falls, Twin Falls, Richland-Kennewick-Pasco, Redding, Portland-Salem expand based on maximum supply availability
Constraints	Shipments of regional system for WA-OR-ID for rail and barge must ≥ sum of minimum shipments to Seattle and Portland from that region (≥5.14 mmt)	Shipments of regional system for WA-OR-ID for rail must ≥ sum of maximum supply in scenario to Seattle and Portland (≥3.94 mmt)	Shipments of regional system for WA-OR-ID for rail is ≤ sum of maximum supply in scenario to Seattle and Portland (≤6.17 mmt)
Regional shipments	WA-OR-ID ships a minimum amount	WA-OR-ID ships a minimum amount in response to shock	Only WA-OR-ID ships in response to shock
Total landing cost	$4,278 million	$4,463 million (4.35% increase)	$4,502 million (5.25% increase)

Table 3 Summary of Baseline and Scenarios using landing costs with CSR system shock

Model	Baseline	Scenario 3A (remove barge, PNW and Northern Plains rail responds)	Scenario 3B (remove barge, PNW rail responds)
Model type	Complete PNW and NP markets respond (segmented markets)	Complete PNW and NP markets respond (segmented markets)	Only WA-OR-ID regions respond; remaining regions are set to baseline solution (segmented markets)
Transportation costs	Long-run average	25% higher	25% higher
Wheat Price	Long-run average	Long-run average	Long-run average
Export demand	Long-run average	Long-run average	Long-run average
Supply	All supply regions ship based on maximum supply availability	All supply regions ship based on maximum supply availability	Casper, Spokane, Idaho Falls, Twin Falls, Richland-Kennewick-Pasco, Redding, Portland-Salem expand based on maximum supply availability
Constraints	Shipments of regional system for WA-OR-ID for rail and barge must ≥ sum of minimum shipments to Seattle and Portland from that region (≥5.14 mmt)	Shipments of regional system for WA-OR-ID for rail must ≥ sum of maximum supply in scenario to Seattle and Portland (≥2.34 mmt)	Shipments of regional system for WA-OR-ID for rail is ≤ sum of maximum supply in scenario to Seattle and Portland (≤6.31 mmt)
Regional shipments	WA-OR-ID ships a minimum amount	WA-OR-ID ships a minimum amount in response to shock	Only WA-OR-ID ships in response to shock
Total landing cost	$4,278 million	$4,699 million (9.87% increase)	$4,768 million (11.47 % increase)

Table 4 Summary of Baseline and Scenarios using landing costs with CSR system shock

Model	**Baseline**	**Scenario 4A (remove barge, PNW and Northern Plains rail responds)**	**Scenario 5A (remove barge, PNW and Northern Plains rail responds)**
Model type	Complete PNW and NP markets respond (segmented markets)	Complete PNW and NP markets respond (segmented markets)	Complete PNW and NP markets respond (segmented markets)
Transportation costs	Long-run average	Long-run average	Long-run average
Wheat Price	Long-run average	Long-run average	6% higher
Export demand	Long-run average	Decrease export demand 1.25% per 1% increase in total landing costs => 1.25*6.62% = 8.28%	Long-run average
Supply	All supply regions ship based on maximum supply availability	All supply regions ship based on maximum supply availability	All supply regions ship based on maximum supply availability
Constraints	Shipments of regional system for WA-OR-ID for rail and barge must ≥ sum of minimum shipments to Seattle and Portland from that region (≥5.14 mmt)	Shipments of regional system for WA-OR-ID for rail must ≥ sum of maximum supply in scenario to Seattle and Portland (≥2.34 mmt)	Shipments of regional system for WA-OR-ID for rail must ≥ sum of maximum supply in scenario to Seattle and Portland (≥2.34 mmt)
Regional shipments	WA-OR-ID ships a minimum amount	WA-OR-ID ships a minimum amount in response to shock	WA-OR-ID ships a minimum amount in response to shock
Total landing cost	$4,278 million	$4,179 million (2.30% decrease)	$4,791 million (12% increase)

Figure 1. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 1A (Right)

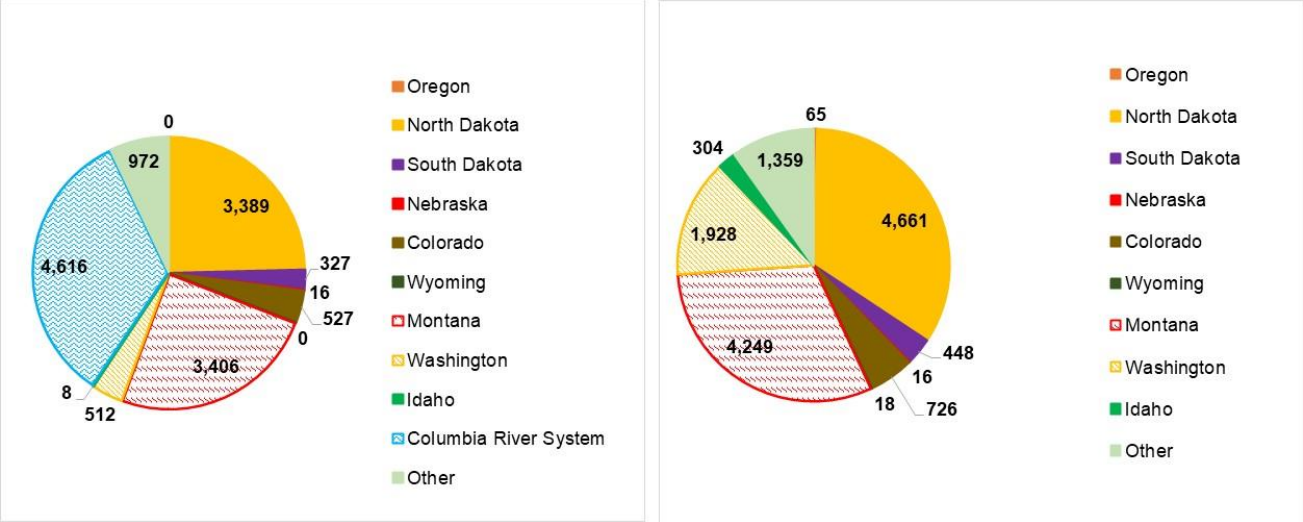


Figure 2. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 1B (Right)

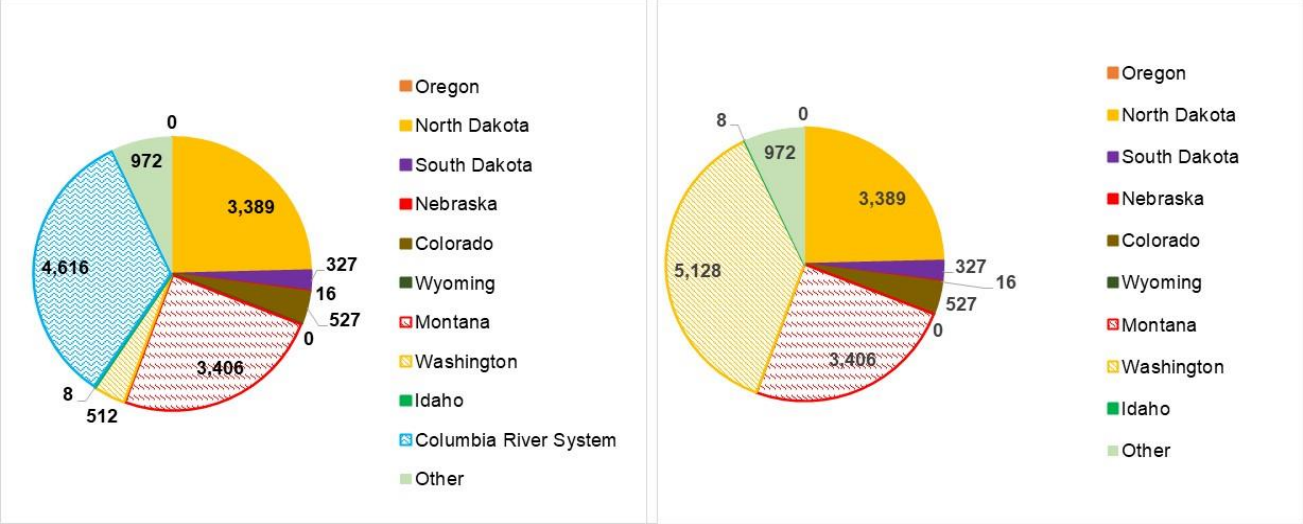


Figure 3. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 2A (Right)

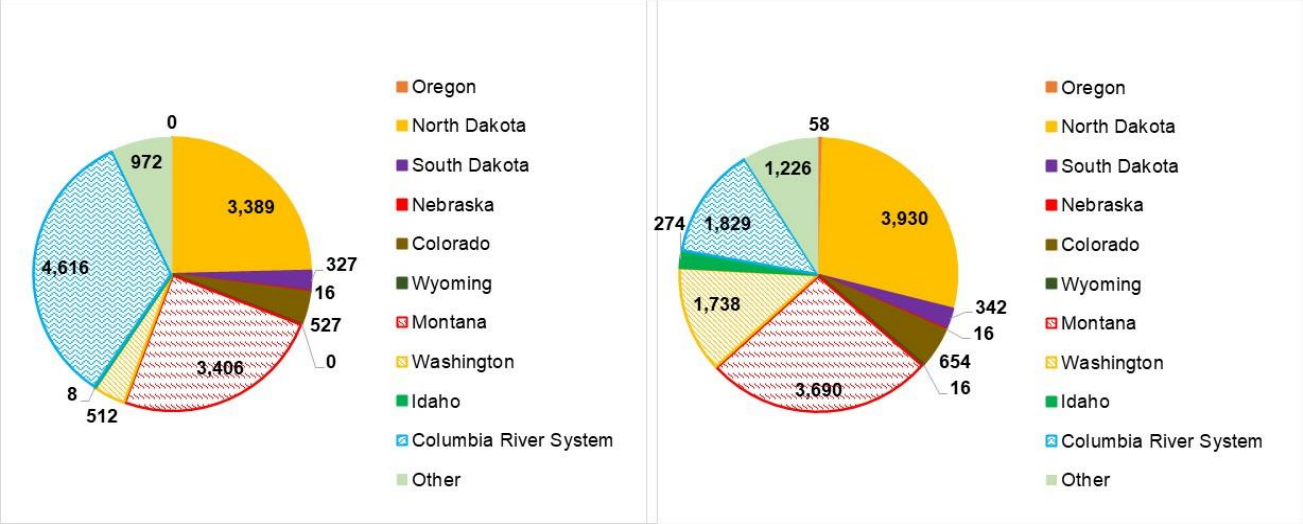


Figure 4. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 2B (Right)

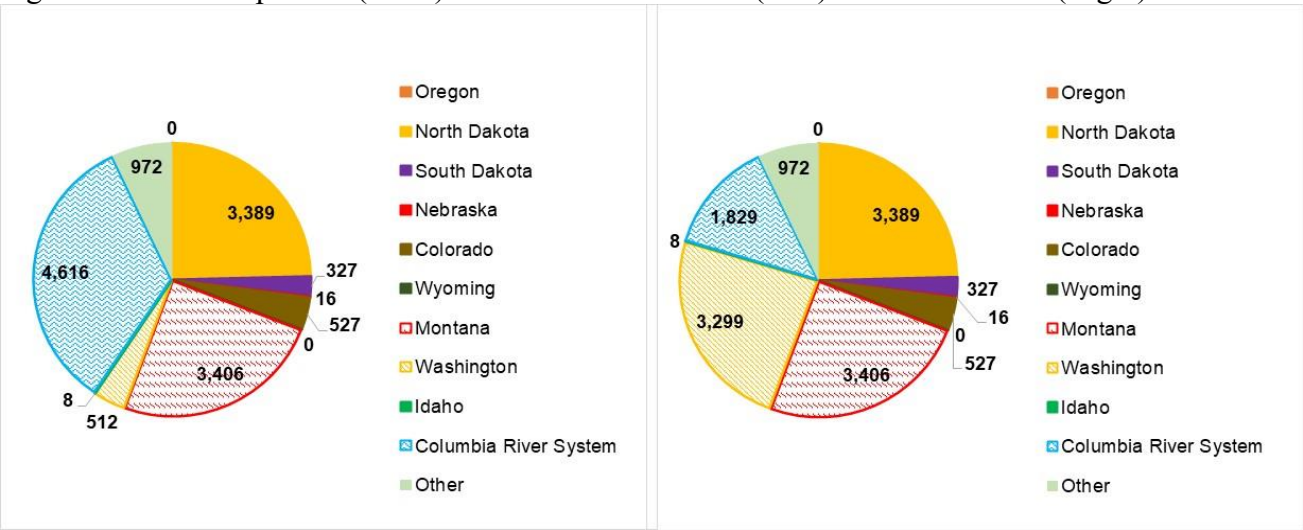


Figure 5. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 3A (Right)

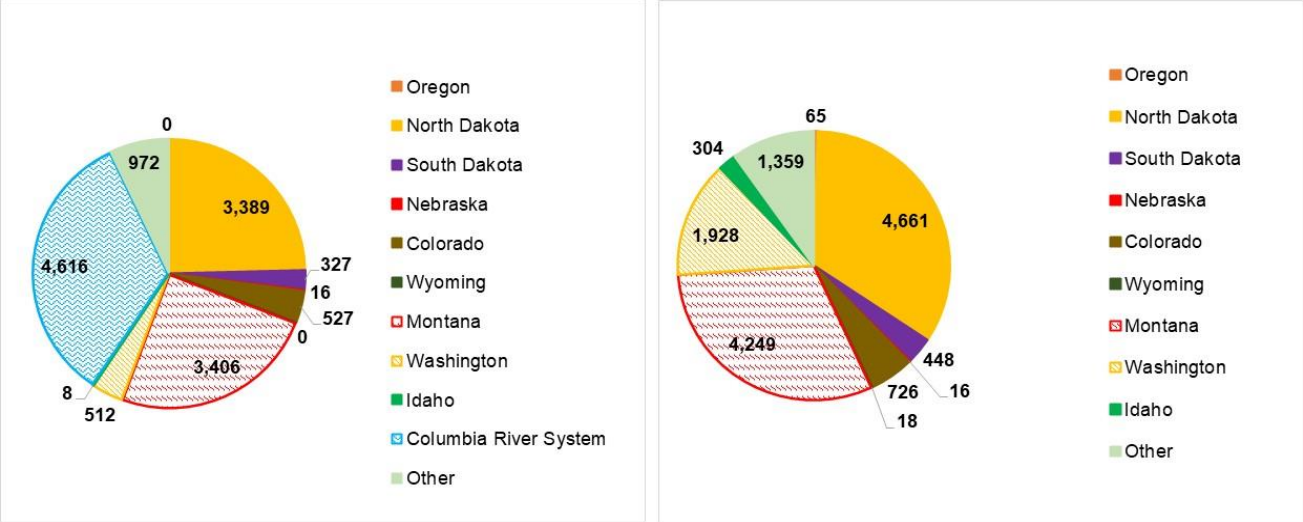


Figure 6. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 3B (Right)

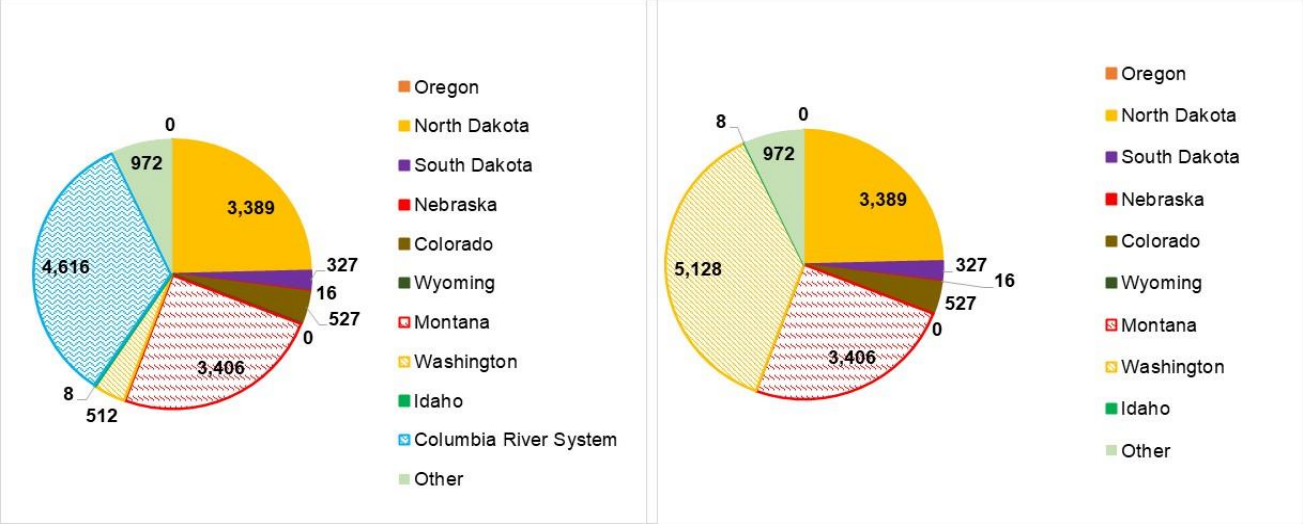


Figure 7. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 4A (Right)

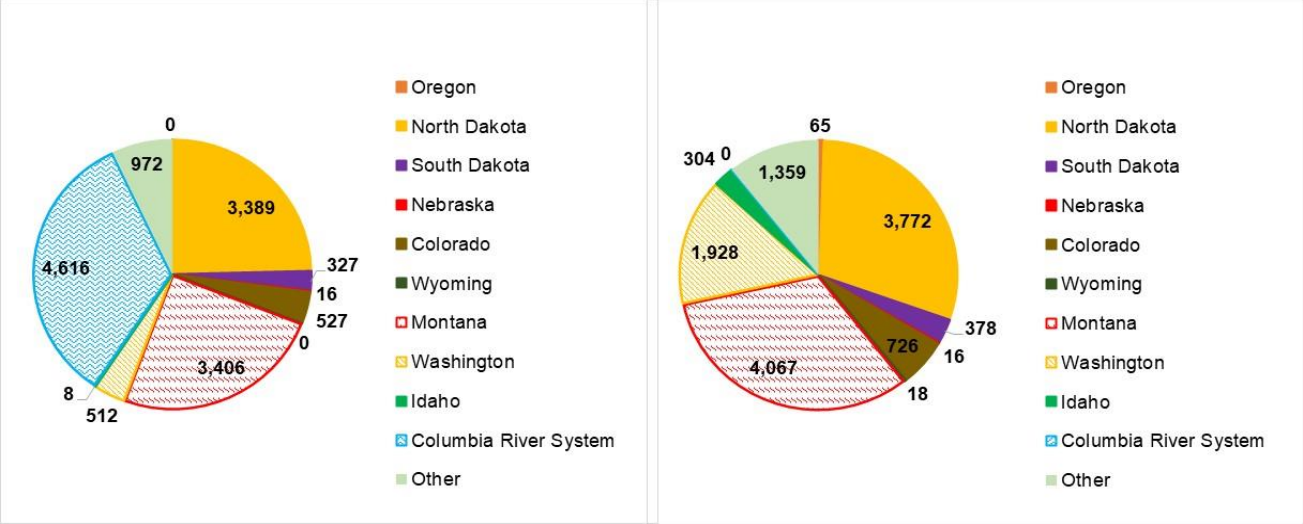
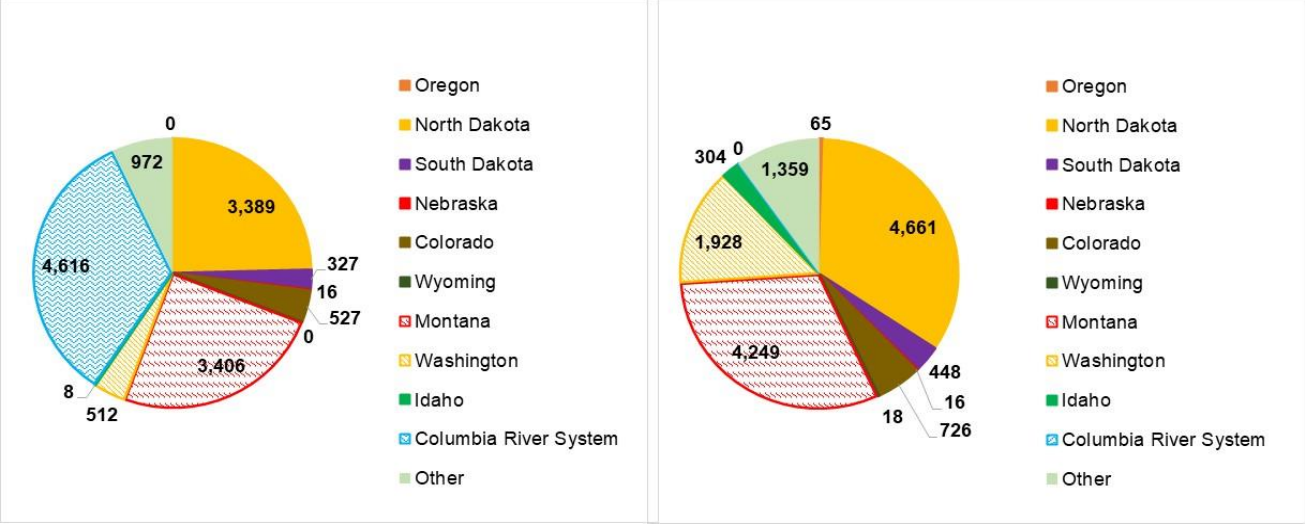


Figure 8. Wheat Shipments (TMT) to Portland in Baseline (Left) and Scenario 5A (Right)



Supplementary Material A. Input data and sources

Rail volume and cost data

We use the Public Use Carload Waybill Sample data (STB, 2026). Specifically, expanded volume (mt) and final expanded freight revenue ($) are used, after aggregating the data for all ownership types (privately owned, railroad owned, and TTX owned). Rail transportation cost for each route from origin area to termination area is computed as:

$$tc_{sd}^{rail} = \frac{final\ expanded\ freight\ revenue\ in\ \$}{expanded\ volume\ in\ MT}$$

Expanded data are defined as sample data times the theoretical expansion factor provided in the Waybill dataset. Final freight revenue includes freight revenue, transit charges, and miscellaneous charges. Outliers in rail cost data are replaced with average of remaining years for the same origin area for 2 supply regions: Twin Falls, ID and Wichita, KS-OK.

Barge volume data

For volumes shipped by barge, we use USACE Waterborne Cargo and Trips data for annual foreign and domestic waterborne commerce moved on the PNW system for wheat. Specifically, we use the "Columbia River, Mouth to International Boundary" waterway. This is consistent with what Jessup at al. (2024) focused on for their analysis of CSR system: the Columbia River between Vancouver, WA and The Dalles, OR; the Columbia River from The Dalles, WA to McNary Dam; and the Snake River from Pasco, WA to Lewiston, ID.

From the different traffic directions, we choose Downbound/West/South (sum of Inbound Receiving, Outbound Shipping, Local, Thru) since this is the direction wheat exports move (USACE, 2020).

Barge cost data

USDA AMS publishes barge costs for the PNW only for 2022 onwards. Thus, we estimated the barge cost for 2017-2021 using the following formula:

$$tc_{sd}^{barge} = weighted\ average\ rail\ cost \cdot \frac{cost\ of\ barge\ to\ Portland}{cost\ of\ rail\ to\ Portland}$$

Weighted average rail cost is computed with rail final expanded freight revenue ($/mt) for each ownership type, origin area, termination area, weighted by relevant volume (mt), destined for PNW ports, with rail cost from surrounding regions in WA-OR-ID. Ratio of barge and rail cost in multimodal transportation options in PNW is from Casavant and Jessup (2005) and Train and

Wilson (2006); $2.6 per ton-mile vs $3.7 per ton-mile. So, the barge cost is about 70% of the rail cost.

USDA AMS (2026d) barge rates for downbound grain averages for calendar year (2022-2024) and estimated barge rates (2017-2021) are provided in Table A.7.

Truck costs

We use USDA AMS (2026c) data for North Central (100 miles distance) and National (25 miles distance) converted to $ per mt. We assume these costs to be Truck-to-Elevator, not Truck-to-Port. We use the 25-mile radius distance data for shipping from farm/elevator to rail from regions where there is adequate rail service available. There are exceptions for regions without adequate rail service, such as North Dakota, South Dakota, and Montana. In this case, we use the 100 miles radius data. For barge, the 25-mile cost: $4.22-4.38 per mt is used (Jessup et al. (2024) assume 30 miles for the CSR system). For most rail, we use the 25-mile cost of $4.22-4.38 per mt (Unidentified, Minneapolis-St. Paul, MN-WI-IA, Sioux Falls, SD-IA-MN-NE, Omaha, NE-IA-MO, Wichita, KS-OK, Denver-Boulder-Greeley, CO-KS-NE, Scottsbluff, NE-WY, Casper, WY-ID-UT, Spokane, WA-ID, Idaho Falls, ID-WY, Twin Falls, ID, Richland-Kennewick-Pasco, WA, North Platte, NE-CO, Chicago-Gary-Kenosha, IL-IN-WI, Portland-Salem, OR-WA, and Redding, CA-OR, Grand Island, NE). For Montana, ND and SD rail, the 100-mile cost of $11.10-13.30 per mt is used (Grand Forks, ND-MN, Minot, ND, Bismarck, ND-MT-SD, Fargo-Moorhead, ND-MN, Aberdeen, SD, Rapid City, SD-MT-NE-ND, Billings, MT-WY, Great Falls, MT).

Secondary rail car market premium/discount

Average secondary rail car market premium/discount for BNSF-GF and UP-Pool ($ per mt) are computed for calendar year from USDA AMS (2026a). BNSF premium is added to Grand Forks, ND-MN, Minot, ND, Bismarck, ND-MT-SD, Fargo-Moorhead, ND-MN, Aberdeen, SD, Rapid City, SD-MT-NE-ND, Sioux Falls, SD-IA-MN-NE, Scottsbluff, NE-WY, Casper, WY-ID-UT, Billings, MT-WY, Great Falls, MT. UP premium is added to Denver-Boulder-Greeley, CO-KS-NE, Spokane, WA-ID, Idaho Falls, ID-WY, Twin Falls, ID, North Platte, NE-CO. Average of UP and BNSF is added to Minneapolis-St. Paul, MN-WI-IA, Omaha, NE-IA-MO, Wichita, KS-OK, Richland-Kennewick-Pasco, WA, Chicago-Gary-Kenosha, IL-IN-WI, Unidentified, Grand Island, NE, Portland-Salem, OR-WA, Redding, CA-OR.

Secondary Rail Market is where shippers trade the rights to guaranteed delivery of rail cars from a specific railroad for specific delivery periods. These rights to the delivery of guaranteed railcars consist of rail cars that were purchased in the primary market or as a result of a contract guaranteeing delivery of railcars in return for placing privately owned rail cars in the railroad's car fleet.

Wheat price

Wheat price is from LSEG Data & Analytics., based on the 10 closest elevators to the BEA regional definition for each supply region. Wheat classes that are shipped by rail and barge differ, as well as by production region. HRS and HRW refer to derived cash prices that take basis (for either HRS or HRW) over the Minneapolis Wheat Exchange.

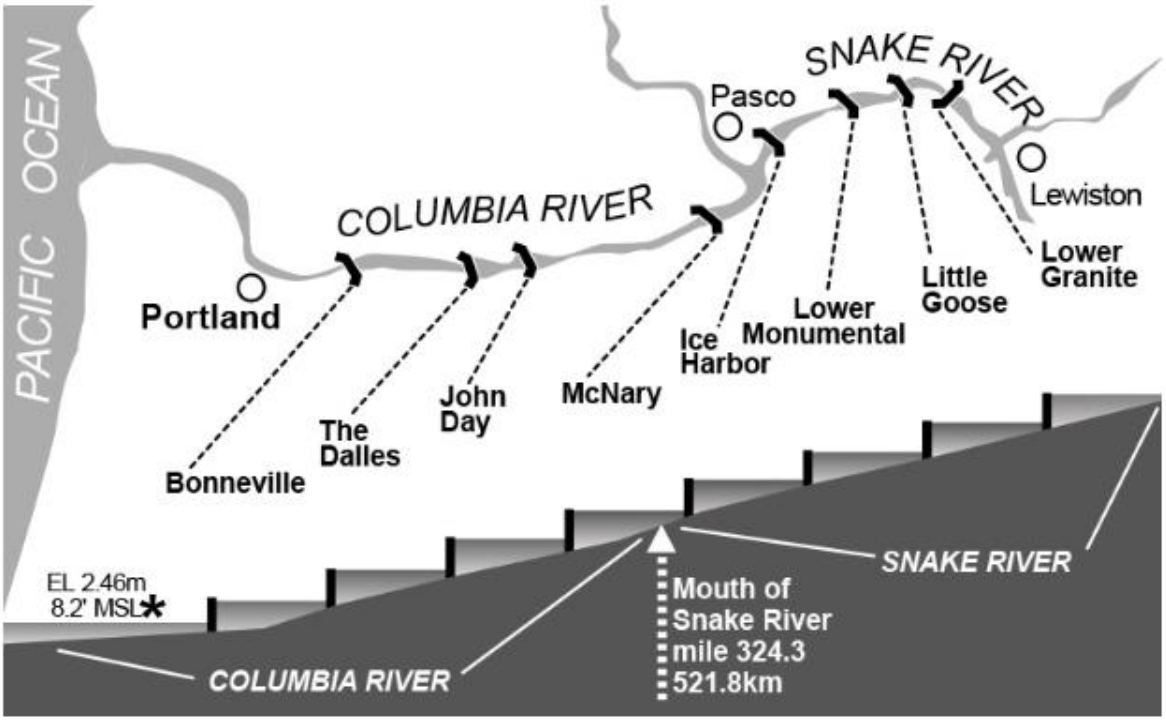
Supplementary Material A Transportation Model Description

Table A.1. Termination and Origin Areas used from Waybill dataset for rail shipping

Termination Area	Origin Area	
167: Portland-Salem, OR-WA	0	Unidentified
	110	Grand Forks, ND-MN
	64	Chicago-Gary-Kenosha, IL-IN-WI
	111	Minot, ND
	112	Bismarck, ND-MT-SD
	113	Fargo-Moorhead, ND-MN
	114	Aberdeen, SD
	115	Rapid City, SD-MT-NE-ND
	116	Sioux Falls, SD-IA-MN-NE
	118	Omaha, NE-IA-MO
	121	North Platte, NE-CO
	122	Wichita, KS-OK
	141	Denver-Boulder-Greeley, CO-KS-NE
	142	Scottsbluff, NE-WY
	144	Billings, MT-WY
	145	Great Falls, MT
	147	Spokane, WA-ID
	148	Idaho Falls, ID-WY
	149	Twin Falls, ID
	169	Richland-Kennewick-Pasco, WA
	143	Casper, WY-ID-UT
	120	Grand Island, NE
	167	Portland-Salem, OR-WA
	165	Redding, CA-OR
170: Seattle-Tacoma-Bremerton, WA	0	Unidentified
	64	Chicago-Gary-Kenosha, IL-IN-WI
	107	Minneapolis-St. Paul, MN-WI-IA
	111	Minot, ND
	112	Bismarck, ND-MT-SD
	142	Scottsbluff, NE-WY
	144	Billings, MT-WY
	145	Great Falls, MT
	147	Spokane, WA-ID
	148	Idaho Falls, ID-WY
	167	Portland-Salem, OR-WA
	169	Richland-Kennewick-Pasco, WA

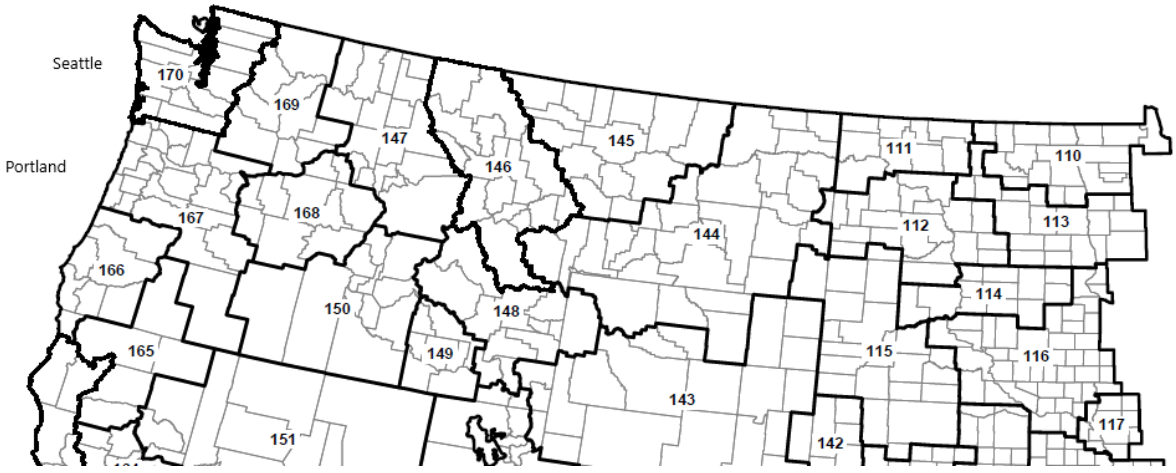
Source: STB (2026)

Figure A.1. Columbia-Snake Inland Waterway Source: USACE (2026)



<https://www.nwp.usace.army.mil/locks/bonneville-dam/>

Figure A.2. Pacific Northwest supply regions



Source: BEA (1995) and STB (2026)

Table A2. Wheat export shipments in the Pacific Northwest (in metric tons)

Year	Barge shipments to Portland	Rail shipments to Portland	Rail shipments to Seattle
2017	4,070,250	10,547,485	147,128
2018	4,211,015	8,475,116	297,172
2019	4,165,366	9,853,090	180,348
2020	4,616,015	10,234,262	103,862
2021	4,410,611	8,853,647	0

Note: Barge shipments of wheat are Downbound/West/South shipments for Columbia River, Mouth to International Boundary. Rail shipments of wheat are expanded metric tons for termination areas 167 and 170.
Source: STB (2026) and USACE (2026)

Table A.3. Input data sources for transportation model

Parameters	Definition	Data source
tc_{sd}^{rail}	Rail cost for wheat shipments to Portland and Seattle ports ($ per mt)	STB Waybill dataset
tc_{sd}^{barge}	Barge cost for wheat shipments to Portland port ($ per mt)	Casavant and Jessup (2005) survey, weighted average cost of rail in WA-OR-ID supply regions to Portland port
sec_s	Average secondary rail car market premium/discount ($ per mt)	AMS dataset
tc_s^{truck}	Truck cost from farm to elevator ($ per mt)	AMS dataset
$price_s^{wheat}$	Average cash price based on 10 closest elevators to each supply region. Wheat classes differ for each supply location (SRW, HRS, HRW for rail and SWW for barge delivered wheat) ($ per mt)	LSEG Data & Analytics.
a_s for rail	Sum of rail-delivered wheat from each supply region to Portland and Seattle ports (mt)	STB Waybill dataset
a_s for barge	Barge shipments of wheat for the complete CSR System to Portland port (mt)	USACE dataset
b_d	Export demand at Portland and Seattle ports (mt)	Sum of total rail- and barge-delivered wheat to each port

Table A.4. Average transportation costs to Portland

Origin area (BEA region)		Transport cost (dollars per MT)
0	Unidentified	27.94
64	Chicago-Gary-Kenosha, IL-IN-WI	104.40
110	Grand Forks, ND-MN	66.48
111	Minot, ND	66.56
112	Bismarck, ND-MT-SD	64.46
113	Fargo-Moorhead, ND-MN	66.71
114	Aberdeen, SD	65.64
115	Rapid City, SD-MT-NE-ND	63.71
116	Sioux Falls, SD-IA-MN-NE	63.54
118	Omaha, NE-IA-MO	133.32
120	Grand Island, NE	59.27
121	North Platte, NE-CO	52.24
122	Wichita, KS-OK	83.15
141	Denver-Boulder-Greeley, CO-KS-NE	58.49
142	Scottsbluff, NE-WY	90.97
143	Casper, WY-ID-UT	66.78
144	Billings, MT-WY	59.28
145	Great Falls, MT	52.21
147	Spokane, WA-ID	23.23
148	Idaho Falls, ID-WY	71.80
149	Twin Falls, ID	87.28
165	Redding, CA-OR	36.74
167	Portland-Salem, OR-WA	23.52
169	Richland-Kennewick-Pasco, WA	28.46
CSR	Barge	20.05

Source: based on Waybill dataset for 2017-2021 (STB, 2026) and barge formula to Portland, with truck costs (USDA AMS, 2026c) included.

Table A.5. Average transportation costs to Seattle

Origin area (BEA region)		Transport cost (dollars per mt)
0	Unidentified	48.11
64	Chicago-Gary-Kenosha, IL-IN-WI	59.60
107	Minneapolis-St. Paul, MN-WI-IA	53.38
111	Minot, ND	85.24
112	Bismarck, ND-MT-SD	79.18
142	Scottsbluff, NE-WY	78.30
144	Billings, MT-WY	60.82
145	Great Falls, MT	70.65
147	Spokane, WA-ID	28.95
148	Idaho Falls, ID-WY	56.75
169	Richland-Kennewick-Pasco, WA	28.94

Source: based on Waybill dataset for 2017-2021 to Seattle (STB, 2026), with truck costs (USDA AMS, 2026c).

Table A.6. Secondary car market premium/discount ($ per mt)

Year	Railroad	Value
2017	BNSF	2.59
2017	UP	0.04
2018	BNSF	3.27
2018	UP	0.26
2019	BNSF	3.41
2019	UP	0.49
2020	BNSF	2.58
2020	UP	0.56
2021	BNSF	2.49
2021	UP	1.75

Source: USDA AMS (2026a)

Table A.7. Barge costs

Year	Weighted average rail cost for WA-OR-ID ($ per mt)	Rail to Portland cost (ton-mile)	Barge to Portland cost (ton-mile)	Barge costs ($ per mt)	Source
2017	21.32	3.7	2.6	14.98	Authors' estimation
2018	21.10	3.7	2.6	14.83	Authors' estimation
2019	21.17	3.7	2.6	14.88	Authors' estimation
2020	20.92	3.7	2.6	14.70	Authors' estimation
2021	25.78	3.7	2.6	18.12	Authors' estimation
2022	NA			17.67	AMS (2026d)
2023	NA			17.70	AMS (2026d)
2024	NA			17.56	AMS (2026d)

Source: based on Waybill dataset for 2017-2021 to Seattle (STB, 2026), Casavant and Jessup (2005), Train and Wilson (2006), USDA AMS (2026d). Some data are NA since public use sample Waybill dataset summarized by USDA AMS is only reported until 2020.

Table A.8. Average landing costs to Portland, 2017-2021

Origin Area		Landing cost (dollars per mt)
0	Unidentified	298.18
64	Chicago-Gary-Kenosha, IL-IN-WI	429.98
110	Grand Forks, ND-MN	329.95
111	Minot, ND	316.90
112	Bismarck, ND-MT-SD	317.67
113	Fargo-Moorhead, ND-MN	328.84
114	Aberdeen, SD	336.72
115	Rapid City, SD-MT-NE-ND	313.54
116	Sioux Falls, SD-IA-MN-NE	340.84
118	Omaha, NE-IA-MO	379.02
120	Grand Island, NE	347.88
121	North Platte, NE-CO	340.24
122	Wichita, KS-OK	352.52
141	Denver-Boulder-Greeley, CO-KS-NE	309.68
142	Scottsbluff, NE-WY	344.43
143	Casper, WY-ID-UT	359.86
144	Billings, MT-WY	339.22
145	Great Falls, MT	328.09
147	Spokane, WA-ID	359.75
148	Idaho Falls, ID-WY	370.95
149	Twin Falls, ID	420.94
165	Redding, CA-OR	424.06
167	Portland-Salem, OR-WA	398.03
169	Richland-Kennewick-Pasco, WA	337.16
200	Barge	276.29

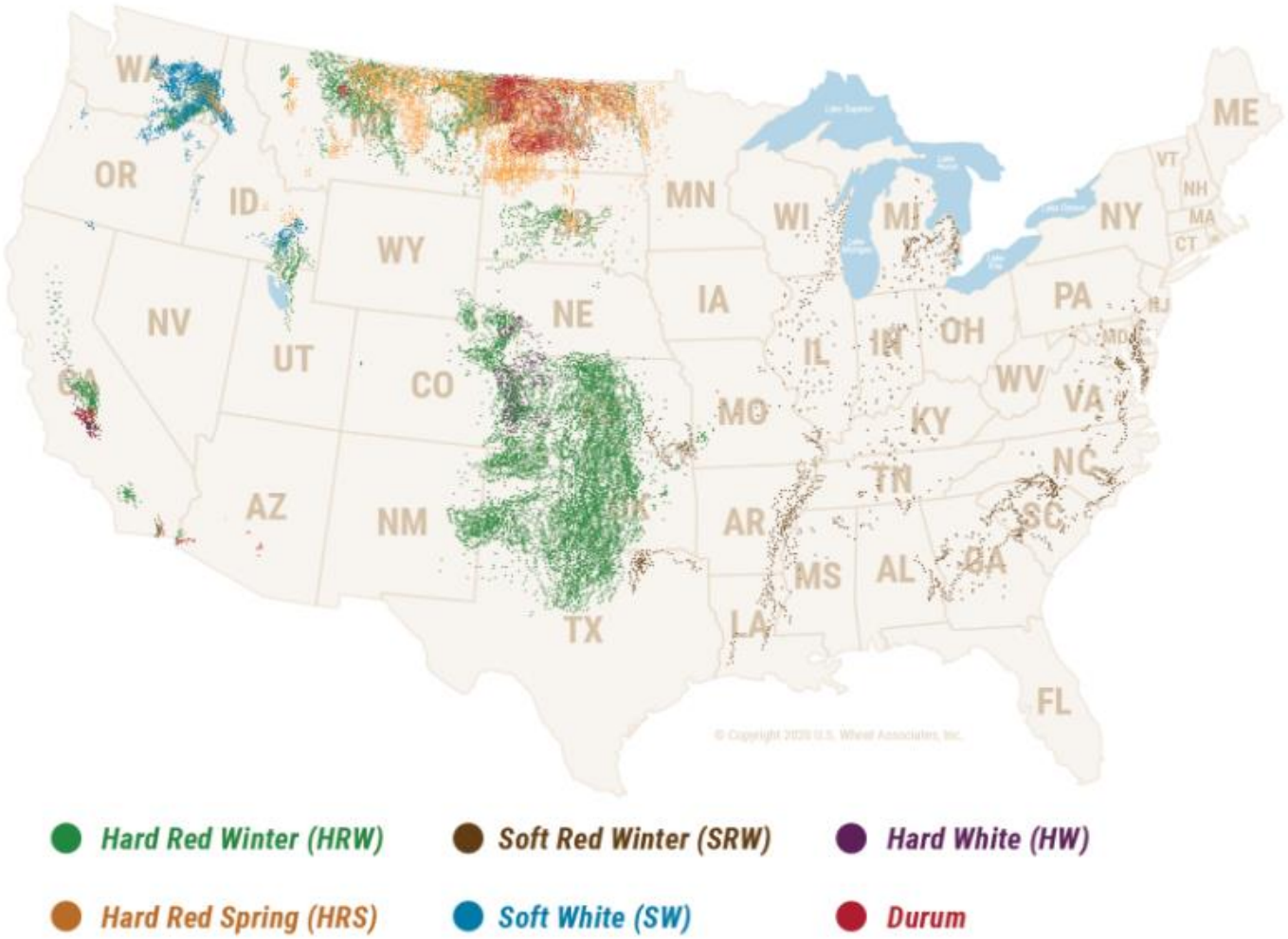
Source: based on Waybill dataset for 2017-2021 (STB, 2026) and barge formula to Portland, with truck costs included (USDA AMS, 2026c), LSEG (2026).

Table A.9. Average landing costs to Seattle, 2017-2021

Origin area		Landing cost (dollars per mt)
0	Unidentified	294.51
64	Chicago-Gary-Kenosha, IL-IN-WI	284.32
107	Minneapolis-St. Paul, MN-WI-IA	304.76
111	Minot, ND	326.52
112	Bismarck, ND-MT-SD	324.74
142	Scottsbluff, NE-WY	319.13
144	Billings, MT-WY	315.99
145	Great Falls, MT	347.34
147	Spokane, WA-ID	349.23
148	Idaho Falls, ID-WY	329.98
169	Richland-Kennewick-Pasco, WA	301.04

Source: Based on Waybill dataset for 2017-2021 to Seattle (STB, 2026), with truck costs (USDA AMS, 2026c), LSEG (2026).

Figure A.3 Wheat Classes in United States



Source: U.S. Wheat Associates (2024)

Supplementary Material B. Baseline and Scenario Results

Table B.1. Comparison of results across studies on Columbia Snake River system

Study	Scenario	Methodology	Shipping costs	Volume change in rail	Volume change in barge
FCS Group (2020)	Removal of Snake River Navigation	Expert interviews	Increase by $0.20-$0.40 per bushel (50%-100%)	60% shift to rail, 10% shift to truck	30% shift to barge
USACE (2020)	Removal of Snake River Navigation	Transportation model	Increase by $0.07-$0.24 per bushel (9.6%-32.9%)	1.82 mmt – 0.02 mmt increase	1.8 mmt-0.02 mmt decline for CSR total; 0.2 mmt-2.05 mmt increase for Columbia River portion
Jaller (2022)	Removal of Snake River ports	Cost minimization	Increase by 14% ($0.11 per bushel)	1.46 mmt	1.46 mmt
ERS model (2026)	Removal of Barge (all of CSR), 4.62 mmt shock	Transportation model with PNW and NP response	Landing costs increase by 6.62% ($327.68 per mt, $8.92 per bushel);	4.62 mmt	4.62 mmt for CSR barge

ERS model (2026)	Removal of Barge (all of CSR), 4.62 mmt shock	Transportation model with PNW response	Landing costs increase by 8.71% ($334.11 per mt, $9.09 per bushel);	4.62 mmt	4.62 mmt for CSR barge
ERS model (2026)	Reduction of Barge (Snake River), 2.79 mmt shock	Transportation model with PNW and NP response	Landing costs increase by 4.35% ($320.69 per mt, $8.74 per bushel)	2.79 mmt	2.79 mmt for Snake River barge
ERS model (2026)	Reduction of Barge (Snake River), 2.79 mmt shock	Transportation model with PNW response	Landing costs increase by 5.25% ($323.46 per mt, $8.80 per bushel)	2.79 mmt	2.79 mmt for Snake River barge

Note: All studies listed, except FCS Group (2020), focused exclusively on wheat.

Table B2. Wheat shipments in Baseline to Portland

Origin area	**Optimal transport volume (mt)**	**Data Range (2017-2021)**
Unidentified	972,376	596,740-972,376
Chicago-Gary-Kenosha, IL-IN-WI	0	9,095
Minneapolis-St. Paul, MN-WI-IA	0	0
Grand Forks, ND-MN	746,632	377,482-746,632
Minot, ND	1,251,240	948,909-1,247,400
Bismarck, ND-MT-SD	788,460	371,054-788,460
Fargo-Moorhead, ND-MN	602,244	223,014-602,244
Aberdeen, SD	50,408	25,220-50,408
Rapid City, SD-MT-NE-ND	272,173	100,598-272,173
Sioux Falls, SD-IA-MN-NE	4,048	20,240-145,592
Omaha, NE-IA-MO	0	4,440
Grand Island, NE	0	50,412-97,670
North Platte, NE-CO	0	29,409-73,820
Wichita, KS-OK	0	1,200-231,556
Denver-Boulder-Greeley, CO-KS-NE	527,476	51086-527476
Scottsbluff, NE-WY	15,661	78,304-151,506
Casper, WY-ID-UT	0	6,090-13,200
Billings, MT-WY	615,427	1,141,488-2,077,434
Great Falls, MT	2,790,783	2,529,027-2,790,783
Spokane, WA-ID	308,797	975,698-1,194,249
Idaho Falls, ID-WY	5,909	29,544-11,6240
Twin Falls, ID	1,608	8,040-104,536
Redding, CA-OR	0	8,425-15,760
Portland-Salem, OR-WA	0	32,676-46,910
Richland-Kennewick-Pasco, WA	203,584	52,380-203,584
Barge	4,616,015	4,070,250-4,616,014

Note: Total landing costs are $4,277,539,529.

Table B3. Wheat shipments in Baseline to Seattle

Origin Area	**Optimal transport volume (mt)**	**Data Range (2017-2021)**
Unidentified	0	13,752-117,100
Chicago-Gary-Kenosha, IL-IN-WI	145,702	19,320-268,600
Minneapolis-St. Paul, MN-WI-IA	0	3,160-7,600
Grand Forks, ND-MN	0	0
Minot, ND	0	3,840
Bismarck, ND-MT-SD	0	5,316
Fargo-Moorhead, ND-MN	0	0
Aberdeen, SD	0	0
Rapid City, SD-MT-NE-ND	0	0
Sioux Falls, SD-IA-MN-NE	0	0
Omaha, NE-IA-MO	0	0
Grand Island, NE	0	0
North Platte, NE-CO	0	0
Wichita, KS-OK	0	0
Denver-Boulder-Greeley, CO-KS-NE	0	0
Scottsbluff, NE-WY	0	4,040
Casper, WY-ID-UT	0	0
Billings, MT-WY	0	8,916-40,484
Great Falls, MT	0	4,980
Spokane, WA-ID	0	3,816-18,420
Idaho Falls, ID-WY	0	4,020-12,288
Twin Falls, ID	0	0
Redding, CA-OR	0	0
Portland-Salem, OR-WA	0	8,960
Richland-Kennewick-Pasco, WA	0	5,352-9,384

Notes: Total landing costs are $4,277,539,529.

Table B.4. Wheat shipments in Scenario 1A to Portland (with CSR system shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	1,337,530	38%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	1,027,013	38%
Minot, ND	1,721,115	38%
Bismarck, ND-MT-SD	1,084,548	38%
Fargo-Moorhead, ND-MN	828,403	38%
Aberdeen, SD	69,338	38%
Rapid City, SD-MT-NE-ND	374,381	38%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	725,558	38%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	18,157	
Billings, MT-WY	410,394	-33%
Great Falls, MT	3,838,799	38%
Spokane, WA-ID	1,647,971	434%
Idaho Falls, ID-WY	159,891	2606%
Twin Falls, ID	143,792	8842%
Redding, CA-OR	21,678	
Portland-Salem, OR-WA	64,526	
Richland-Kennewick-Pasco, WA	280,035	38%
Barge	0	-100%

Notes: Total landing costs are $4,560,886,311.

Table B.5. Wheat shipments in Scenario 1A to Seattle (with CSR system Shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,560,886,311.

Table B.6. Wheat shipments in Scenario 1B to Portland (with CSR system shock)

Origin Area	**Optimal transport volume (mt)**	**% change from Baseline**
Unidentified	972,376	0%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	746,632	0%
Minot, ND	1,251,240	0%
Bismarck, ND-MT-SD	788,460	0%
Fargo-Moorhead, ND-MN	602,244	0%
Aberdeen, SD	50,408	0%
Rapid City, SD-MT-NE-ND	272,173	0%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	527,476	0%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	0	
Billings, MT-WY	615,427	0%
Great Falls, MT	2,790,783	0%
Spokane, WA-ID	4,371,465	1316%
Idaho Falls, ID-WY	5,909	0%
Twin Falls, ID	1,608	0%
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	756,931	272%
Barge	0	-100%

Notes: Total landing costs are $4,650,291,233.

Table B.7. Wheat shipments in Scenario 1B to Seattle with (CSR system shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,650,291,233.

Table B.8. Wheat shipments in Scenario 2A to Portland (with Snake River shock)

Origin Area	**Optimal transport volume (mt)**	**% change from Baseline**
Unidentified	1,205,971	24%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	653,854	-12%
Minot, ND	1,551,826	24%
Bismarck, ND-MT-SD	977,872	24%
Fargo-Moorhead, ND-MN	746,921	24%
Aberdeen, SD	0	-100%
Rapid City, SD-MT-NE-ND	337,557	24%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	654,192	24%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	16,371	
Billings, MT-WY	228,298	-63%
Great Falls, MT	3,461,215	24%
Spokane, WA-ID	1,485,877	381%
Idaho Falls, ID-WY	144,164	2340%
Twin Falls, ID	129,649	7963%
Redding, CA-OR	19,546	
Portland-Salem, OR-WA	58,179	
Richland-Kennewick-Pasco, WA	252,491	24%
Barge	1,829,148	-60%

Notes: Total landing costs are $4,463,474,569.

Table B.9. Wheat shipments in Scenario 2A to Seattle (with Snake River shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,463,474,569.

Table B.10. Wheat shipments in Scenario 2B to Portland (with Snake River Shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	972,376	0%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	746,632	0%
Minot, ND	1,251,240	0%
Bismarck, ND-MT-SD	788,460	0%
Fargo-Moorhead, ND-MN	602,244	0%
Aberdeen, SD	50,408	0%
Rapid City, SD-MT-NE-ND	272,173	0%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	527,476	0%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	0	
Billings, MT-WY	615,427	0%
Great Falls, MT	2,790,783	0%
Spokane, WA-ID	2,737,860	787%
Idaho Falls, ID-WY	5,909	0%
Twin Falls, ID	1,608	0%
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	561,388	176%
Barge	1,829,148	-60%

Notes: Total landing costs are $4,502,048,288.

Table B.11. Wheat shipments in Scenario 2B to Seattle (with Snake River Shock)

Origin Area	**Optimal transport volume (mt)**	**% change from Baseline**
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,502,048,288.

Supplementary Material C. Sensitivity analyses results

Table C.1. Wheat shipments in Scenario 3A to Portland (with CSR system shock)

Origin Area	**Optimal transport volume (mt)**	**% change from Baseline**
Unidentified	1,337,530	38%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	1,027,013	38%
Minot, ND	1,721,115	38%
Bismarck, ND-MT-SD	1,084,548	38%
Fargo-Moorhead, ND-MN	828,403	38%
Aberdeen, SD	69,338	38%
Rapid City, SD-MT-NE-ND	374,381	38%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	725,558	38%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	18,157	
Billings, MT-WY	410,394	-33%
Great Falls, MT	3,838,799	38%
Spokane, WA-ID	1,647,971	434%
Idaho Falls, ID-WY	159,891	2606%
Twin Falls, ID	143,792	8842%
Redding, CA-OR	21,678	
Portland-Salem, OR-WA	64,526	
Richland-Kennewick-Pasco, WA	280,035	38%
Barge	0	-100%

Notes: Total landing costs are $4,699,757,126.

Table C.2. Wheat shipments in Scenario 3A to Seattle (with CSR system Shock)

Origin Area	**Optimal transport volume (mt)**	**% change from Baseline**
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,699,757,126.

Table C.3. Wheat shipments in Scenario 3B to Portland (with CSR system shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	972,376	0.00%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	746,632	0.00%
Minot, ND	1,251,240	0.00%
Bismarck, ND-MT-SD	788,460	0.00%
Fargo-Moorhead, ND-MN	602,244	0.00%
Aberdeen, SD	50,408	0.00%
Rapid City, SD-MT-NE-ND	272,173	0.00%
Sioux Falls, SD-IA-MN-NE	4,048	0.00%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	527,476	0.00%
Scottsbluff, NE-WY	15,661	0.00%
Casper, WY-ID-UT	0	
Billings, MT-WY	615,427	0.00%
Great Falls, MT	2,790,783	0.00%
Spokane, WA-ID	4,371,465	1315.64%
Idaho Falls, ID-WY	5,909	0.00%
Twin Falls, ID	1,608	0.00%
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	756,931	271.80%
Barge	0	-100.00%

Notes: Total landing costs are $4,768,300,658.

Table C.4. Wheat shipments in Scenario 3B to Seattle (with CSR system Shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0.00%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,768,300,658.

Table C.5. Wheat shipments in Scenario 4A to Portland (with CSR system shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	1,337,530	38%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	138,038	-82%
Minot, ND	1,721,115	38%
Bismarck, ND-MT-SD	1,084,548	38%
Fargo-Moorhead, ND-MN	828,403	38%
Aberdeen, SD	0	-100%
Rapid City, SD-MT-NE-ND	374,381	38%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	725,558	38%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	18,157	
Billings, MT-WY	228,298	-63%
Great Falls, MT	3,838,799	38%
Spokane, WA-ID	1,647,971	434%
Idaho Falls, ID-WY	159,891	2606%
Twin Falls, ID	143,792	8842%
Redding, CA-OR	21,678	
Portland-Salem, OR-WA	64,526	
Richland-Kennewick-Pasco, WA	280,035	38%
Barge	0	-100%

Notes: Total landing costs are $4,179,025,520.

Table C.6. Wheat shipments in Scenario 4A to Seattle (with CSR system Shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	133,638	-8%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,179,025,520.

Table C.7 Wheat shipments in Scenario 5A to Portland (with CSR system shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	1,337,530	38%
Chicago-Gary-Kenosha, IL-IN-WI	0	
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	1,027,013	38%
Minot, ND	1,721,115	38%
Bismarck, ND-MT-SD	1,084,548	38%
Fargo-Moorhead, ND-MN	828,403	38%
Aberdeen, SD	69,338	38%
Rapid City, SD-MT-NE-ND	374,381	38%
Sioux Falls, SD-IA-MN-NE	4,048	0%
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	725,558	38%
Scottsbluff, NE-WY	15,661	0%
Casper, WY-ID-UT	18,157	
Billings, MT-WY	410,394	-33%
Great Falls, MT	3,838,799	38%
Spokane, WA-ID	1,647,971	434%
Idaho Falls, ID-WY	159,891	2606%
Twin Falls, ID	143,792	8842%
Redding, CA-OR	21,678	
Portland-Salem, OR-WA	64,526	
Richland-Kennewick-Pasco, WA	280,035	38%
Barge	0	-100%

Notes: Total landing costs are $4,791,030,686.

Table C.8. Wheat shipments in Scenario 5A to Seattle (with CSR system Shock)

Origin Area	Optimal transport volume (mt)	% change from Baseline
Unidentified	0	
Chicago-Gary-Kenosha, IL-IN-WI	145,702	0%
Minneapolis-St. Paul, MN-WI-IA	0	
Grand Forks, ND-MN	0	
Minot, ND	0	
Bismarck, ND-MT-SD	0	
Fargo-Moorhead, ND-MN	0	
Aberdeen, SD	0	
Rapid City, SD-MT-NE-ND	0	
Sioux Falls, SD-IA-MN-NE	0	
Omaha, NE-IA-MO	0	
Grand Island, NE	0	
North Platte, NE-CO	0	
Wichita, KS-OK	0	
Denver-Boulder-Greeley, CO-KS-NE	0	
Scottsbluff, NE-WY	0	
Casper, WY-ID-UT	0	
Billings, MT-WY	0	
Great Falls, MT	0	
Spokane, WA-ID	0	
Idaho Falls, ID-WY	0	
Twin Falls, ID	0	
Redding, CA-OR	0	
Portland-Salem, OR-WA	0	
Richland-Kennewick-Pasco, WA	0	

Notes: Total landing costs are $4,791,030,686.