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Northwest Export Shipping of Potato Products

— Hinterland Delineation And Growth Potential

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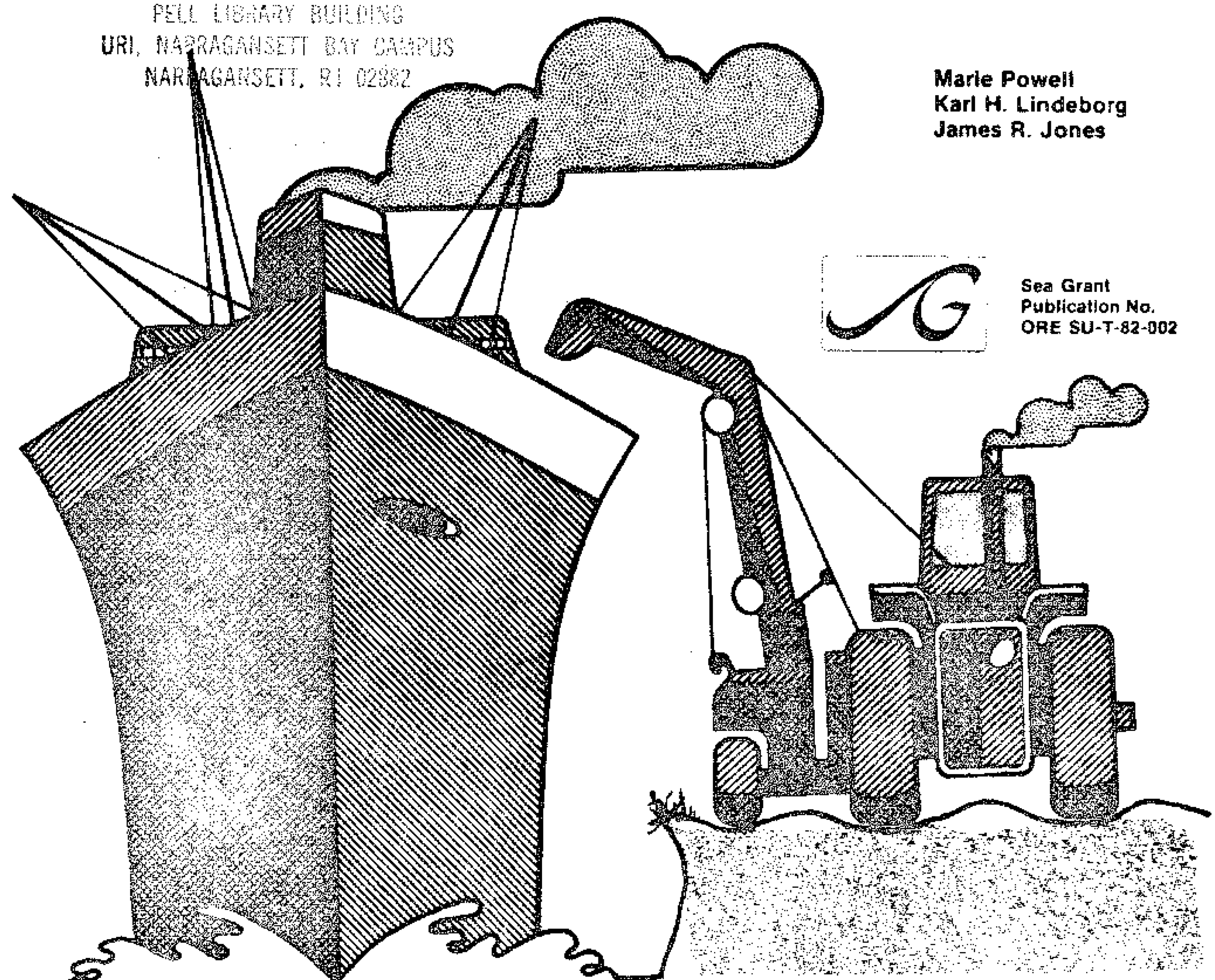

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Northwest Export Shipping of Potato Products: Hinterland Delineation And Growth Potential

Marie Powell, Karl H. Lindeborg and James R. Jones

Historically in the Pacific Northwest (PNW), the agricultural and maritime transportation sectors have mutually supported each other. Grains, fruits, vegetables and other products produced in surplus in the region depend heavily upon foreign markets and, at the same time, contribute a significant portion of revenues to Columbia River and Puget Sound ocean ports. With the recent extension of slack water navigation to eastern Washington and Lewiston, Idaho, and the advent of container-on-barge service on the Columbia-Snake, waterborne transportation as an alternative available in the export physical distribution system of the region has received increased attention.

Potatoes are one of the most important crops in the Northwest. This region contributed an average of 43 percent to U.S. production in the 1970s, making it the largest single producing region in the country. The Northwest supplied more than 80 percent of all potato products processed. To date; potato products have been marketed primarily in domestic U.S. markets. Nationally, only about 2 percent of annual production has gone into export. As potato production has increased, the industry has been confronted with the problem of overproduction. Many doubt whether traditional domestic markets can absorb any more supplies; thus interest in developing overseas trade is likely to grow. This study is concerned with analyzing whether potatoes are potentially suitable products to be shipped to overseas markets via Columbia/Snake river ports.

Study Objectives

This report's purposes were to examine the export market for potato products and to assess the implications of historical and developing trade for Columbia/Snake river transportation. Specific objectives included:

1. To identify production and processing regions for potatoes, and to trace the use of the potato crop within the U.S. to determine the supply of potatoes available for export at representative origins.
2. To determine least-cost shipping patterns and shipping modes for fresh and processed potatoes from production regions to final domestic and export destinations with emphasis on determining whether these products lie in the hinterland of Columbia/Snake deep water and shallow water ports.
3. To project future export shipments of potato and potato products through Columbia/Snake river ports.

Study Methodology and Procedures

A linear programming transshipment procedure was used to analyze the export marketing system for potatoes. Transshipment models are distinguished from transportation models by the addition of an intermediate transfer point or interface between origin and destination. The interface provides for a transfer from the inland transportation mode to an oceangoing vessel.

The objective function normally represents the minimized transportation costs to shippers. In this study, the costs of production and processing are included in the objective function to be minimized as well.

Separate models were run to analyze fresh and processed potatoes. Dehydrated products were selected as the type of processed potato to be studied. Potato flakes and granules are the most common form of dehydrated product. A lack of historical export data on frozen potato products prevented their being included in the analysis. Frozen products began to be reported in 1979.

The Objective Function

The mathematical representation of the transshipment model is:

$$\text{Minimize } PPTC = \sum_i C_i P_i + \sum_i \sum_j \sum_k T_{ijk} X_{ijk}$$

Subject to:

$$P_i = \sum_j \sum_k X_{ijk}$$

$$\sum_i X_{ijk} \leq S_i$$

$$\sum_j X_{ijk} = D_j$$

$$X_{ijk} \geq 0$$

$$\sum_i S_i \geq \sum_j D_j$$

where: PPTC = production, processing and transportation cost of fresh or dehydrated potatoes.

C_i = cost of production and processing of fresh (dehydrated) potatoes at origin i.

P_i = amount of fresh (dehydrated) potatoes processed for shipment at origin i.

T_{ijk} = cost of transporting fresh (dehydrated) potatoes from origin i to destination j by mode k.

X_{ijk} = amount of fresh (dehydrated) potatoes shipped from origin i to destination j by mode k.

S_i = supply of fresh (dehydrated) potatoes at origin i.

D_j = demand for fresh (dehydrated) potatoes at destination j.

Data Requirements

Origins and Destinations — The i and j subscripts of the objective function represent indexes of origin and destination points. They are described here.

Origins representative of the entire nation were selected since potatoes are produced in nearly every state. Fall production contributes the largest proportion to the crop, so fall-producing states were grouped into five major production regions. Within these five, three were also identified as processing regions. The processing industry relies heavily on major, fall, crop-producing areas to get raw products. Thus, processing plants have located in leading, fall-producing states.

Table 1 shows the production and processing regions and their basing points. Production regions consisted of the North Atlantic, Middle Atlantic, North Central, Mountain and Northwest. The Northwest was delineated into two subregions, each with its own basing point. Idaho and Malheur County, Oregon, comprised one of the subregions, and Washington and the rest of Oregon the other. Processing regions included the North Central, North Atlantic and the same subregions of the Northwest.

To simplify the data requirements for the two models, identical basing points were selected wherever possible. The mountain region was represented by Alamosa, Colorado; the North Central by East Grand Forks, Minnesota; the Middle Atlantic by Long Island, New York; and the North Atlantic by Presque Isle, Maine. These are leading production centers within each region. In the Northwest, three basing points were chosen. Idaho Falls, Idaho, represented Idaho and Malheur County, Oregon, for both models. Moses Lake, Washington, represented fresh potato production in Washington and Oregon whereas the Tri-Cities area in Washington represented the processing region. Although this study concerns itself with dehydrated products, the Tri-Cities origin also reflects the broader processing capacity in the region.

Export data were examined for processed and fresh potatoes to determine historical demand for imports by other nations. Five representative foreign destinations for U.S. dehydrated potatoes were selected: Vancouver, British Columbia; Puerto Cabello, Venezuela; Rotterdam, (the) Netherlands; Naples, Italy, and Hong Kong. Seven representative foreign destinations for U.S. fresh potatoes were chosen: Vancouver, British Columbia; Mexico City, Mexico; Santo Domingo, Dominican Republic; Buenos Aires, Argentina; Rotterdam, (the) Netherlands; Naples, Italy; and Hong Kong. Each destination serves as a basing point for other importing countries in the region.

Tables 2 and 3 list the importing countries by region and their representative basing points as well as the average quantity demanded at each destination. The years 1972 to 1978 were used in calculating the average to minimize a distortion occurring in export figures during 1975 to 1977. A drought in Europe during 1974-76 caused U.S. exports to be substantially higher than normal during this period. The average also revealed more about demand over time than a shorter or single-year period. Annual fluctuations are common.

In addition to these origins and destinations, locations serving as transshipment points between the two were necessary. Ports which handled the largest volume of potato exports in the period were selected. Transfer ports for fresh potatoes include Portland, Oregon; Seattle, Washington; New York,

Table 1. Production regions for fresh and processed potatoes.

Basing point	States	Region
Fresh Potatoes		
Idaho Falls, Idaho	Idaho and Malheur Co., Oregon	Northwest
Moses Lake, Wash.	Oregon and Washington	Northwest
Alamosa, Colorado	Colorado, Montana, Nevada, Utah and Wyoming	Mountain
E. Grand Forks, Minnesota	Indiana, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin	North Central
Long Island, New York	New York and Pennsylvania	Middle Altantic
Presque Isle, Maine	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont	North Atlantic
Processed Potatoes		
Idaho Falls, Idaho	Idaho and Malheur Co., Oregon	Northwest
Tri-Cities, Washington	Oregon, Washington	Northwest
E. Grand Forks, Minnesota	Michigan, Minnesota and North Dakota	North Central
Presque Isle, Maine	Maine	North Atlantic

Table 2. U.S. dehydrated potato exports by foreign regions.

Basing point	Region	Quantity[1]
		(1,000 cwt, fwe)
Vancouver	Canada	318.1
Puerto Cabello	Latin America	148.2
	Barbados	.6
	Venezuela	33.2
	Other	114.4
Rotterdam	Northern Europe	2,116.2
	Belgium-Luxemburg	19.1
	Denmark	50.4
	Finland	17.4
	France	465.1
	Ireland	18.9
	Netherlands	112.9
	Sweden	423.1
	United Kingdom	382.2
	West Germany	588.9
	Other	38.2
Naples	Mediterranean	100.0
	Italy	14.5
	Spain	47.3
	Other	38.2
Hong Kong	Asia	1,169.7
	Australia	25.7
	Japan	1,105.8
	Other	38.2
	Total	3,852.2

[1]Includes dehydrated potatoes, flakes and granules. Amounts are given on a fresh-weight-equivalency basis. 1972-78 calendar year average.

Source: USDA Foreign Agricultural Trade Statistical Report, Calendar Years 1972, 1974, 1976 and 1978

Table 3. U.S. fresh potato exports by foreign regions.

Basing point	Region	Quantity[1]
		(1,000 cwt)
Vancouver	Canada	4,000.7
Mexico City	Mexico	219.0
Santo Domingo	Caribbean	148.9
	Bahamas	50.9
	Barbados	8.7
	Bermuda	3.5
	Dominican Republic	6.6
	French West Indies	4.4
	Leeward & Windward Islands	2.2
	Netherland Antilles	8.9
	Panama	5.0
	Trinidad	33.5
	Other	25.2
Buenos Aires	Latin America	133.1
	Argentina	40.8
	Chile	84.6
	Uruguay	7.7
Rotterdam	Northern Europe	1,065.4
	Belgium-Luxemburg	169.9
	France	454.3
	Netherlands	192.2
	Norway	24.7
	Sweden	147.2
	United Kingdom	3.6
	West Germany	73.5
Naples	Mediterranean	367.6
	Algeria	124.0
	Egypt	11.2
	Italy	69.2
	Portugal	138.0
	Other	25.2
Hong Kong	Asia	43.8
	Australia	7.8
	Japan	10.2
	Taiwan	.6
	Other	25.2
	Total	5,978.5

[1]1972-78 calendar year average.

Source: USDA Foreign Agricultural Trade Statistical Report. Calendar years 1971, 1973, 1975, 1977 and 1978.

New York, and Portland, Maine. Transfer ports for processed potatoes included Portland, Oregon; Seattle, Washington; the Bay Area in California; Houston, Texas, and Norfolk, Virginia. The Columbia/Snake river ports of Lewiston, Idaho; Pasco, Washington, and Umatilla, Oregon, were also included in both models. These ports are similar to the other transshipment points except that two transfers occur instead of one. The first is from the inland origin to the river port and the second from the river barge to the oceangoing vessel at the Port of Portland.

Supply and Demand — The procedures used for derivation of supply and demand for fresh and processed potatoes are described here.

1. *Fresh Potatoes* — A vast array of statistics are collected and published on the potato crop each year. Data on the crop's various uses were tabulated and subtracted from the production total in each region to arrive at the potato supply available for export. Reported uses included seed, processing and food consumption. An average of the 1971-77 crop years was used in calculating production data, and an average of the 1972-78 calendar years was used for consumption data thus accounting for the lag which occurs between production and marketing.

The sale of fall-crop potatoes represented available supplies in each region. Seed use was estimated and subtracted from the base supply. Potatoes used in processing frozen and dehydrated products were then subtracted. Potato chip production was determined, and the quantity of potatoes used for making chips was subtracted. Unlike frozen and dehydrated processing, the manufacture of potato chips occurs in all regions.

Table 4. Regional use of potatoes and supply available for export per basing point (1,000 cwt).

Basing points	Production[1]	Seed use[2]	Processing[3]	U.S. demand[4]	Regional surplus	Percent available for export
Idaho Falls, Idaho	76,919	6,113	57,112	12,528	1,166	7%
Moses Lake, Washington	53,658	2,647	34,925	12,664	3,422	22%
Alamosa, Colorado	12,954	1,835	1,219	6,966	2,934	19%
East Grand Forks, Minnesota	52,213	7,178	16,214	25,383	3,438	22%
Long Island, New York	17,532	527	5,186	11,335	484	3%
Presque Isle, Maine	29,181	3,956	11,527	9,523	4,175	27%
U.S. total	242,457	22,256	126,183	78,399	15,619	100%

[1]Consists of potatoes sold for all purposes including food, seed, processing and livestock feed. Average 1971-77 crop years. Source: Potatoes and Sweetpotatoes, USDA, 1972-78.

[2]Based on an optimum distribution system of seed from producing states to consuming regions (a 1972-74 average) according to results of a least-cost linear program. Each region's base was multiplied by the annual incremental increase or decrease in acres planted for the fall crop to arrive at an estimate of the 1971-77 average seed use in each production region. Optimum seed distribution from *Potatoes Optimum use and distribution with comparative costs by major regions of the U.S.* Table 15. Bull. 865, Washington State Univ., 1976. Acres planted information from *Potatoes and Sweetpotatoes*, USDA, 1972-78.

[3]Includes potatoes processed as dehydrated, frozen, canned products, for starch and flour, and for potato chips. Regional totals of potatoes used for chips were reduced by one-third to reflect that fall potatoes comprise about 67 percent of the total chip production. Source Potatoes and Sweetpotatoes, USDA, 1972-78.

[4]Demand for fresh potatoes was approximated by the average quantity shipped from 1972-78 from each production region to the major markets for fruits and vegetables in the U.S. These quantities are from *Fresh fruit and vegetable unload totals for 41 cities reports*, calendar years 1971-78, USDA, 1979. These reports account for about 60 percent of total commercial potato unloads in the U.S., so quantities were increased to estimate total demand.

Domestic demand for fresh potatoes was approximated through data in the USDA fresh fruit and vegetable unload totals for 41 cities reports. These reports record shipments of raw potatoes from the production state to the major distribution centers in the U.S. This data accounts for about 60 percent of total commercial unloads in the U.S.; therefore, the quantities were increased to approximate 100 percent of demand (Barton 1980). These estimates were subtracted from the remaining supply. The difference resulted in the potential supply of fresh potatoes available for export in each region. Expressed as a share of total surpluses in the system, the Presque Isle, Maine, basing point had 27 percent; Moses Lake, Washington, and East Grand Forks, Minnesota, each had 22 percent, while Idaho Falls, Idaho, had 7 percent and Long Island, New York, had 3 percent. Table 4 summarizes the use information.

Exports will not totally reduce regional surpluses. Overproduction nationally has led to situations of excess supply, and domestic and international markets have been unable to absorb the surplus. Diversion programs converting unused potatoes to feed and starch have been popular. Normally less than 2 percent of the national crop has been sold for livestock feed. Excess supplies were left in the system to see where surpluses accumulated.

2. *Dehydrated Potatoes* — Because insufficient data existed, a different procedure was required to derive the supply of processed potatoes potentially available for export at each origin. No reliable method was found for determining the origins of processed products consumed in the U.S.; as a result, the transshipment model was designed to allocate the supply of potatoes to destinations both within the U.S. and in foreign countries.

The supply of dehydrated products at the four production regions was estimated by multiplying the total quantity of potatoes processed at each origin by the average percentage of potatoes used as dehydrated products in the U.S.[1] Table 5 shows the estimated supply at each basing point.

Domestic demand for dehydrated potatoes was estimated by consumption region of the U.S. Six regions were identified — the Northwest, Mountain, South Central, North Central, South Atlantic and Atlantic. Table 6 delineates this and the basing points and the quantity demanded in each region. Fresh-weight-equivalent (fwe) quantities for dehydrated products were used throughout this report at the rate of 6 pounds of raw potatoes required to produce 1 pound of dehydrated (Greig 1978).

3. *Product Homogeneity* — One assumption of the transshipment model of linear programming is product homogeneity (i.e., all fresh potatoes and all potato products are the same). A corollary to this assumption is that receivers of the product have no preference as to its origin. However, the variety differences of potatoes make this assumption unrealistic. For example, the Northwest is noted for production of Russet Burbank potatoes, the Red River Valley for varieties of red potatoes and Maine for white potatoes.

Because the data in the USDA unload reports are derived from actual shipping patterns of raw potatoes, varietal differences in consumption were already accounted for. The lack of product homogeneity was not as critical to fresh exports as to domestic consumption because very little product differentiation of U.S. potatoes exists in world markets. No product differentiation exists among potatoes used for dehydration.

[1]Average 1971-77 national utilization figures. Source: USDA. Potatoes and Sweetpotatoes, Pot-6, ESCS, 1978.

Table 5. Supply of dehydrated potatoes per basing point.

Basing point	Total processing[1] per basing point 1971-77 average		Share of processed[2] potatoes used as dehydrated 1971-77 average		Amount of dehydrated processing at basing point	Percent of total
	(1,000 cwt fwe)				(1,000 cwt fwe)	
Idaho Falls, Idaho	57,017	×	.2746	=	15,656.9	52%
Tri-Cities, Washington	34,235	×	.2746	=	9,400.9	31%
East Grand Forks, Minnesota	9,219	×	.2746	=	2,531.5	8%
Presque Isle, Maine	10,266	×	.2746	=	2,819.0	9%
U.S. total	110,737				30,408.3	100%

[1]Includes potatoes processed as dehydrated products, frozen, canned, starch and flour. Does not include potato chips. Quantities in a fresh-weight-equivalency (fwe).

[2]The average 1971-77 use of potatoes for processed products is:

frozen	65.50%
dehydrated	27.46%
canned	4.03%
starch and flour	3.01%
	100.00%

Source: USDA Potato Stocks, Pot 1-2 Crop Reporting Board, SRS, 1973-78; and USDA Potatoes and Sweetpotatoes, Pot 6 Crop Reporting Board, ESCS, 1972-78.

Production and Processing Costs — Table 7 lists production and processing costs at each origin. In the fresh model, the term "processing" referred to the practice of grading, sizing and packaging potatoes for shipment. The highest production cost was experienced in Idaho, the lowest in Washington.

Table 6. U.S. demand for dehydrated potato products by regions.

Basing point	States	Region	Quantity[1]
			(1,000 cwt, fwe)
Sacramento	California, Idaho, Oregon, Washington	Northwest	3,451
Denver	Arizona, Colorado, Montana, Nevada, New Mexico, Utah, Wyoming	Mountain	1,095
Dallas	Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	South Central	4,290
Chicago	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota	North Central	7,193
Atlanta	Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	South Atlantic	4,154
New York	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont	Atlantic	6,169
	U.S. total		26,352

[1]The quantity demanded was calculated by multiplying consumption per capita of dehydrated potatoes by the population of each state for each year. It is a 1972-78 calendar-year average.

Source: Consumption per capita from Vegetable Situation, TVS-214. USDA, November 1979. Regional population from Statistical Abstract of the United States. U.S. Department of Commerce, Bureau of the Census, 1978.

The lowest cost of processing dehydrated potatoes occurred in the Northwest.

Transportation Modes and Rates — All mathematical inputs have been discussed except the costs of shipping potato products from origin to destination via various modes. These costs by modes are discussed here.[2]

Five inland modes of transportation and two ocean modes were considered in the analysis — breakbulk truck, container-on-truck, breakbulk rail, container-on-railcar, container-on-barge, breakbulk ocean vessel and container ocean vessel. Breakbulk shipping refers to bagged or boxed cargo placed directly into a truck, van, railcar or a ship's hold. Containerized shipping refers to bagged or boxed cargo placed inside a container. The container is then placed on a truck, railcar, barge or container vessel.[3]

Although container-on-barge transportation was included in both models, in reality this mode was available only for dehydrated potatoes. No temperature control is necessary for dehydrated products, but fresh potatoes require some method of air cooling or refrigeration to maintain quality in transit. Barges capable of refrigeration were not available on the Columbia/Snake at the time of the study.

The rates gathered for these transportation modes were those in effect in March of 1980. At that time, truck transportation of fresh potatoes was exempt from ICC regulation, but rail was not. Both rail and truck transportation of dehydrated potato products were regulated by the ICC. Rail transportation has since been exempted from ICC regulation, and the truck and rail industries both appear headed

[2]Baseline shipping activities and their corresponding rates are included in Appendices A and B. Although numerous transportation modes were considered, very few were actually brought into solution.

[3]For a more detailed explanation of transportation modes, see (Belcher 1978).

Table 7. Production and processing costs for fresh and dehydrated potatoes per basing point, 1979.

Basing point	Production cost per cwt[1]	Fresh processing cost per cwt[2]	Dehydrated processing cost per cwt[3]	Total production and processing cost: Fresh	Total production and processing cost: Dehydrated
Idaho Falls, Idaho	$3.80	$2.20	$1.47	$6.00	$5.27
Moses Lake, Washington	2.64	2.20	—	4.84	—
Tri-Cities, Washington	2.64	—	1.47	—	4.11
Alamosa, Colorado	3.15	2.08	—	5.23	—
E. Grand Forks, Minnesota	3.09	1.79	1.52	4.88	4.61
Long Island, New York	3.23	1.62	—	4.85	—
Presque Isle, Maine	3.20	1.25	1.66	4.45	4.86

[1]Costs of production revised from 1978 dollars to 1979 through the index of prices paid by farmers for production items: Ag. Outlook, AO-52. USDA, March 1980.

[2]Fresh processing costs revised from 1975 dollars to 1979 through creation of an index for marketing spreads: Developments in Marketing Spreads for Food Products in 1979, Ag. Econ. Report No. 449, USDA, March 1980.

[3]Dehydrated processing costs revised from 1975 dollars to 1979 through the index of prices of selected food marketing inputs: Developments in Marketing Spreads for Food Products in 1979, Ag. Econ. Report No. 449, USDA, March 1980.

Source: Production costs: Potato Facts, Production Costs. Commodity Economics Division, ESCS, USDA, Winter 1979. Processing costs: Potatoes, Optimum Use and Distribution with Comparative Costs by Major Regions of the U.S. W. Smith Greig and Leroy Blakeslee. College of Agriculture Research Center Bulletin 865, Washington State University, August 1978.

for a period of reduced regulations on the hauling of manufactured and fresh agricultural products. Deregulated rail rates initially appeared to change little from rates quoted under regulation.

Truck rates for hauling fresh potatoes were obtained through a survey of shippers at each origin. Rates for transporting fresh potatoes by rail were supplied by Union Pacific personnel from published rate schedules (Roberts 1980). Dehydrated rail and truck rates were provided from published rate tariffs through a consulting firm (White 1980). Container-on-barge rates were obtained from the Pacific Inland Tariff Bureau. Linear regressions were used to estimate rates on routes where no information existed. The estimates were based on observations of actual rates.

Ocean vessel charges for potato exports were obtained from commodity tariffs of appropriate ocean steamship conferences. The complete ocean charges were comprised of a base rate together with surcharges applying to factors such as fuel costs, foreign currency adjustments or congestion at ports of call. Charges accrued for handling potatoes at each port were added also. No cargo insurance costs were considered.

Shipments of fresh potatoes were assumed to take place in ventilated or refrigerated trailers, railcars and containers, and atmosphere-controlled ocean vessels. Loading of all container shipments was assumed to occur under the shipper's supervision at the point of origin rather than at the port, and loading costs were not included in the transportation charges. They are fairly standard regardless of which mode is used; therefore, they do not affect the relative competitiveness of alternate modes of transportation. For container shipments, no charge was assessed for delivery of the empty container to the shipper for loading. Carriers have in the past absorbed most of the costs of container delivery. Railroads have since been contemplating charging for this service, however.

When the weight of a shipment was a contributing factor to the cost, it was assumed that the highest minimum weight was shipped which would provide the lowest transport cost without injuring the quality of the shipment. Finally, shippers were assumed to choose the transportation modes that offered the lowest transportation charges from origin to destination. Realistically, factors such as service and dependability are often important in the selection, but these factors are difficult to quantify.

Transshipment Model Alternatives and Projections

Using the transshipment model as the analytical tool, first runs were made to analyze the current potato exporting system in the Northwest and the role of transportation on the Columbia Snake rivers in that system. Forecasts based upon simulation runs of these base models were used to examine the potential for increased exports through Northwest ports and to project future levels of export.

The data for the hinterland base models were representative of the present (1979-80) time period. Forecasts for the period 1985-2000 were made using subsequent runs of the models hypothesizing scenarios with changes in supply, overseas demand and energy costs. Of interest were the effects of these changes on hinterland delineation, modal choice, quantities shipped and on total transportation costs in each period.

Potential for Increased Exports — The outlook for frozen and dehydrated exports looks more promising than for fresh. Dehydrated exports in particular are advantageous over fresh potatoes because this processed form results in greatly reduced bulk, and consequently transportation costs are much less. Japan is central to the projected growth of demand for U.S. processed products. The expanding institutional and fast-food markets in that country are the primary reasons for increased export opportunities. Other factors include rising incomes, acceptance of Western style diets and the desire for convenience foods. Growth in the European market has been projected as well but not at as high a rate as the Japanese (Emerson 1978).

Prospects for growth in demand for fresh potatoes appear limited by high transportation costs and trade restrictions. The high water content of potatoes and their perishability result in high transport costs relative to their value. Tariff and nontariff barriers such as phytosanitary requirements which prohibit the importation of U.S. potatoes into Japan and many European countries hamper exports. However, during the drought of 1974-76, trade barriers in Europe were relaxed, and the importation of large quantities of U.S. potatoes did occur. Future fresh potato exports to Europe will likely be tied to years when crop shortfalls there result in excess processing capacity. Exports to Asian countries other than Japan will probably increase. Hong Kong and Singapore are the major markets in Asia, and imports of fresh potatoes primarily supply the hotel business in these countries (The Packer 1980).

Growth in Demand – Increases in demand for fresh potatoes in Asia and dehydrated potatoes in Asia and Europe were incorporated into the hinterland projection. U.S. exports of fresh potatoes to Asia were assumed to increase by 1 percent per year based on projections of potato consumption made by the Japanese government (Japan 1975). No increases were projected for the other regions.

Demand for imports of dehydrated potatoes was estimated through the use of income elasticity for potato products. The elasticity of income is a measure of the responsiveness of the quantity demanded to a change in income, other factors held constant. The mathematical representation is:

$$E_y = \frac{\%\Delta Q}{\%\Delta Y}$$

where: E_y = income elasticity
Q = quantity demanded
Y = income

The percentage change in quantity demanded can be isolated in the equation:

$$\%\Delta Q = (E_y) \times (\%\Delta Y)$$

Estimates of annual growth in income (ΔY) for Asia and Europe were obtained, and income elasticity (E_y) of demand was estimated.[4] Income (real GNP) is expected to increase by 5 percent per year in Asia for the period and by 3 percent per year in Europe (Exxon Corporation 1979). A high and low measure of income elasticity was considered, resulting in projections of an annual increase in demand for processed potatoes within the range of 0.5 and 1.27 percent in Asia and 0.3 and 0.76 percent in Europe. The high estimates were used in the forecasts.

Growth in Supply — The supply of dehydrated potatoes in the Northwest was increased slightly in response to increased demand overseas. Demand in the U.S. was held constant so that changes attributable to increased exporting could be pinpointed. Supplies at non-Northwest basing points were held at static levels also so that expansion of trade through Northwest ports would be highlighted.

The supply of fresh potatoes available for export was adequate to meet the low level of growth anticipated in foreign markets over the projection period. No changes in supply were assumed.

[4]U.S. and Canadian measures of income elasticities were used since no other estimates were available. The reliability of the projections will, of course, depend on how well these measures represent conditions in Asia and Europe.

Energy Efficiency of Inland Modes -- Increased costs of transporting potatoes to market were ranked as the most serious problems that will face Western growers in the future (The Packer 1980). Higher fuel costs have been one of the leading components of transportation cost increases.

As fuel costs rise, the rates charged to shippers also rise. The amount of the increase will vary depending on the mode because the fuel required to ship a given weight a given distance varies by mode. Trucks have been estimated to obtain 1,956.6 cwt miles to 1 gallon of fuel, railcars 3,958 cwt miles and barges 10,489.2 cwt miles (Barton 1980). Thus, the barge mode is impacted less by fuel cost increases than the other modes and rail less than truck. Since Columbia River deep water ports are favored by access to barge, this differential effect could work in their favor at the expense of Puget Sound ports.

These estimates of energy efficiencies were used to examine the effects of rising fuel costs on inland rates of transportation. This was done by dividing the January 1980 wholesale price of fuel (the price in effect when the transportation rates were quoted) by the hundredweight miles per gallon estimates listed above to arrive at a base cost of fuel for each mode. The increase for each period in the base fuel costs per mile for the three modes was determined and multiplied by the number of miles in each route. This resulted in the increase in each transportation rate attributable to the rising price of fuel. This amount was then added to the original rate. Symbolically, the formula is:

$$R = B + \left(\frac{X-Y}{Z}\right)m \quad \text{where,}$$

R = new transportation rate caused by increased energy costs.
B = original base rate.
X = increase in fuel cost per gallon over base.
Y = base fuel cost per gallon.

Table 8. Summary of Model Alternatives — Assumptions.

Time period	Fresh model		Processed model	
Base	Model representing current least-cost exporting system. Historical levels of supply and export.	Run with and without container-on-barge mode available.	Model representing current least-cost exporting system. Historical levels of supply and export.	Run with and without container-on-barge mode available.
1985	Scenario of 5% increase over base in exports to Asia.		Scenario of 6% increase over base in exports to Asia, 4% to Europe.	
1990	Scenario of 10% increase over base in exports to Asia. Fuel costs increased to 50% over base.		Scenario of 12% increase over base in exports to Asia, 7% to Europe. Fuel costs increased to 50% over base.	
1995	Scenario of 15% increase over base in exports to Asia. Fuel costs increased to 100% over base.		Scenario of 18% increase over base in exports to Asia, 11% to Europe. Fuel costs increased to 100% over base.	
2000	Scenario of 20% increase over base in exports to Asia. Fuel costs increased to 150% over base.		Scenario of 24% increase over base in exports to Asia, 14% to Europe. Fuel costs increased to 150% over base.	

Z = cwt miles per gallon mode estimate.

m = miles in route.

Fuel prices were estimated to rise by 25 percent over the base in 1985, 50 percent in 1990, 100 percent in 1995 and 150 percent in 2000. Because only fuel costs were allowed to vary, the effects of real energy cost increases on inland shipping modes were isolated.

Summary of Model Alternatives — Base hinterland models for fresh and processed potatoes were designed to represent the current least-cost potato exporting system in the U.S. Base models were also run without including container-on-barge services at Columbia/Snake river ports to examine the impact of this mode on Northwest shipping.

Forecasts of the least-cost exporting systems in 1985, 1990, 1995 and the year 2000 were made using the original hinterland models. The 1985 projections hypothesized increased demand in Asia and Europe for dehydrated potatoes and increases in Asia for fresh potatoes. A 25 percent real increase in the cost of fuel for inland transportation modes was incorporated also.

Projections for 1990, 1995 and 2000 encompassed further increases in demand for potatoes in Asia and Europe as well as a slight growth in the supply of dehydrated potatoes at Northwest origins. Increased fuel costs of 50 percent, 100 percent and 150 percent over the base were introduced in the forecasts to portray the effects of rising energy costs on the competitive positions of inland modes of transport in the future. Table 8 presents a summary of runs made with the base and forecasting models.

Results

The transshipment models generate information on the least-cost system involved with producing, processing and shipping dehydrated potatoes to U.S. and foreign destinations and the least-cost transportation system for producing, packaging and shipping fresh potatoes for export. The most efficient routes including interfacing ports between origins and destinations are delineated, and the most competitive modes serving those routes are identified. The sensitivity of each transportation mode to changes in its rate is also disclosed. The results here are tabulated according to these topics.

The base models of the transshipment analysis were designed to represent as closely as possible the alternatives existing in the real world; thus, how well the results of the models conform to actual experience is of interest. The selection of transshipment ports was fairly representative of past experience in the Northwest. Fresh exports were directed exclusively through Seattle while processed exports were shipped through Portland. Although in reality each port receives both, Seattle has captured most of the export trade in fresh potatoes while Portland has exported most of the processed potatoes. Locational advantages are in large part determining factors since Seattle is closer to the important fresh production area surrounding Moses Lake, and Portland is the more economical outlet for processing plants established along the Columbia River.

The choice of shipping modes coincided with real practices also. Fresh potatoes are transported primarily by breakbulk shipping methods whereas containerized shipping is preponderant for dehydrated. Container shipping of fresh potatoes has experienced problems in the past arising from the potato's perishability. Because of the high fixed costs, refrigerated containers (reefers) are most often used to transport higher valued commodities than fresh potatoes. Containers are quite suitable for transporting dehydrated potatoes which benefit from nonperishability, reduced bulk and the added value which accompanies processing. These nonrate considerations did not enter the model's selection process, however, except to the extent that they were reflected in the combined rate structures for each modal alternative.

A. Processed Potatoes

Origin to Port by Mode — The base hinterland model provided the initial distribution system at lowest cost for processed potatoes. Export scenarios were projected in 5-year increments over the period 1985-2000. Table 9 gives shipments from each origin to domestic and port destinations. The shipping modes and quantities transported are provided also. In all five model scenarios, processed potato export shipments were transferred to ocean vessels at Portland and Houston. Seattle, the Bay Area or Norfolk were not chosen as transshipment points. Various modes were used between origins and port destinations, but domestic shipments (those to be consumed here rather than overseas) were transported in all instances by the conventional, breakbulk rail mode.

Shipments from Idaho Falls did not enter the export market until the 1995 and 2000 year forecasts. Projected shipments in these years were less than 1 percent of the total, indicating that from a least-cost standpoint Idaho Falls is better suited to supplying U.S. markets since Washington and Oregon processors can ship to foreign markets for less. The export shipment was routed in both cases through Houston, and it was delivered by the breakbulk rail mode.

The Tri-Cities were projected as the major exporting origin in every model. In the base run, 40 percent of the supply in the Washington-Oregon region was destined for foreign markets. By the year 2000, this percentage was up to 45 percent. The bulk of this dehydrated potato traffic was delivered to Portland via the container-on-barge mode loaded at the port of Pasco. Another 3 percent was shipped directly to Vancouver, British Columbia, by breakbulk rail throughout the period.

The results suggest that the area immediately adjacent to the Columbia River is a natural hinterland for the port of Portland, and the container-on-barge mode is particularly advantageous to these localities. A less aggregative model for the Columbia Basin was run to further analyze the degree to which this hinterland extended to areas further away from the river, and the use that container-on-barge would or would not receive from these more distant origins. Five representative points depicted locations of processing plants in Washington and Oregon which had the capability to influence the container-on-barge issue — Moses Lake, Othello, Connell and Tri-Cities, Washington, and Hermiston, Oregon. The rates for this model were generated through estimating equations developed by linear regression techniques. Table 10 shows the results. Moses Lake and Othello were delineated as origins lying exclusively in Seattle's hinterland while the Tri-Cities and Hermiston lay in Portland's domain. The breakdown between the hinterland of the two ports occurred in Connell, Washington. Both Seattle and Portland were shown as receiving export shipments from Connell.

The container-on-barge mode was used exclusively for Portland's shipments. Connell and the

Table 9. Processed potato projections: Origin to U.S. and port destination by mode.

Model alternatives	U.S. destination	Quantity	Mode[2]	Ocean port	Quantity	Mode[2]	% exported
		(1,000 cwt fwe[1])			(1,000 cwt fwe[1])		
Idaho Falls							
Base model[3]	Sacramento	3,003	Rail	None	None	None	
	Chicago	7,193	Rail				
	Dallas	4,290	Rail				
	New York	966	Rail				
Total		15,452[4]					0
1985 projection	Sacramento	3,149	Rail	None	None	None	
	Chicago	7,193	Rail				
	Dallas	4,290	Rail				
	New York	966	Rail				
Total		15,598[4]					0
1990 projection	Sacramento	2,153	Rail	None	None	None	
	Denver	1,095	Rail				
	Chicago	7,193	Rail				
	Dallas	4,290	Rail				
	New York	966	Rail				
Total		15,697[4]					0
1995 projection	Sacramento	2,254	Rail	Houston	148	Breakbulk rail	
	Denver	1,095	Rail				
	Chicago	7,193	Rail				
	Dallas	4,290	Rail				
	New York	818	Rail				
Total		15,798[4]					0.9
2000 projection	Denver	1,095	Rail	Houston	148	Breakbulk rail	
	Chicago	7,193	Rail				
	Dallas	4,290	Rail				
	Atlanta	2,348	Rail				
	New York	818	Rail				
Total		15,892[4]					0.9
Tri-Cities							
Base model	Sacramento	448	Rail	Vancouver, B.C.[5]	318	Breakbulk rail	
	Denver	1,095	Rail	Pasco	3,386	Container truck	
	Atlanta	4,154	Rail	Portland	3,386	Container barge	
Total		9,401					39.4
1985 projection	Sacramento	302	Rail	Vancouver, B.C.	318	Breakbulk rail	
	Denver	1,095	Rail	Pasco	3,532	Container truck	
	Atlanta	4,154	Rail	Portland	3,532	Container barge	
Total		9,401					41.0
1990 projection				Vancouver, B.C.	318	Breakbulk rail	
	Sacramento	1,298	Rail	Pasco	3,678	Container truck	
	Atlanta	4,154	Rail	Portland	3,678	Container barge	
Total		9,448					44.3
1995 projection				Vancouver, B.C.	318	Breakbulk rail	
	Sacramento	1,197	Rail	Pasco	3,826	Container truck	
	Atlanta	4,154	Rail	Portland	3,826	Container barge	
Total		9,495					43.6
2000 projection				Vancouver, B.C.	318	Breakbulk rail	
	Sacramento	3,451		Pasco	3,972	Container truck	
	Atlanta	1,806		Portland	3,972	Container barge	
Total		9,547					44.9

(Table 9 continues next page)

Tri-Cities interfaced with the river port at Pasco in the model while Hermiston's potatoes were trucked to the port of Umatilla for transfer to the river barge. In the case of Connell exports, the rate that induced the shipment to Seattle was a breakbulk rail and breakbulk ocean vessel combination. It was less expensive than the combined truck, barge and ocean rate for transporting goods on the Columbia/Snake.

Destination from U.S. Port by Mode — The transshipment model depicts the quantities of dehydrated potatoes shipped from each port to overseas destinations. The most cost-effective ocean mode is selected in conjunction with the most competitive inland mode. Table 11 presents information on the supplying ports for each foreign destination and the type of ocean vessel used in each projection period.

Portland was projected as the predominant port origin for dehydrated exports. The European destination (Rotterdam), the Mediterranean destination (Naples) and the Asian destination (Hong Kong) were always supplied from Portland, and the shipments at all times moved by container vessel, arriving at Portland via container-on-barge navigation on the Columbia River. The only destination not served by Portland was the Latin American basing point of Puerto Cabello. Houston was projected as the supplying port, also by container vessel, for all of Puerto Cabello's imports. The model underlines the fact that Portland is well suited economically and geographically to transshipping processed potato exports from the Lower Columbia Basin.

Sensitivity Analysis — Sensitivity analysis indicates how much an activity's rate can vary before the level of that activity changes in the solution. Once the value of an activity in the basis changes, the solution is no longer at an optimum level, and the objective function is not at the minimum. Table 12 shows the activity sensitivity in the base hinterland model for dehydrated potatoes.

Table 10. Port hinterland delineations for processed potatoes in Washington and Oregon.

Origin	River port	Mode	Ocean port	Mode	Quantity
					(1,000 cwt fwe)
Moses Lake	—	—	Seattle	C. truck	678
Othello	—	—	Seattle	B.B. rail	677
Connell	—	—	Seattle	B.B. rail	493
Connell	Pasco	C. truck	Portland	C. barge	184
Tri-Cities	Pasco	C. truck	Portland	C. barge	677
Hermiston	Umatilla	C. truck	Portland	C. barge	677

Table 9 (continued).

Model alternatives	U.S. destination	Quantity	Mode[2]	Ocean port	Quantity	Mode[2]	% exported
		(1,000 cwt fwe[1])			(1,000 cwt fwe[1])		
East Grand Forks							
Base model	New York	2,384	Rail	Houston	148	Container rail	
Total		2,532					5.8
1985 projection	New York	2,384	Rail	Houston	148	Container rail	
Total		2,532					5.8
1990 projection	New York	2,384	Rail	Houston	148	Container rail	
Total		2,532					5.8
1995 projection	New York	2,532	Rail	None	None	None	
Total		2,532					0
2000 projection	New York	2,532	Rail	None	None	None	
Total		2,532					0
Presque Isle							
Base model	New York	2,819	Rail	None	None	None	
Total		2,819					0
1985 projection	New York	2,819	Rail	None	None	None	
Total		2,819					0
1990 projection	New York	2,819	Rail	None	None	None	
Total		2,819					0
1995 projection	New York	2,819	Rail	None	None	None	
Total		2,819					0
2000 projection	New York	2,819	Rail	None	None	None	
Total		2,819					0

[1]fwe = fresh weight equivalency.

[2]Breakbulk truck and breakbulk rail were the only modes considered for U.S. destinations. Modes considered for ocean ports included breakbulk truck, breakbulk rail, container truck, container rail and container barge.

[3]The base model was comprised of data averaged from 1971-78. It is representative of the present time period.

[4]An untransported surplus accumulated at Idaho Falls in each model. The surplus was 205 units in the base run, 59 units in the 1985 projection, 38 units in 1990, 16 units in 1995 and 8 units in 2000.

[5]Vancouver, B.C., is a final destination rather than a transshipment point.

Many of the transportation modes are highly sensitive to changes in their rates. Rates for the ocean modes were particularly susceptible to increases. For example, the rate for a container vessel from Portland to Rotterdam or to Naples cannot rise above the current level without causing changes in these variables in the solution. The rate from Portland to Hong Kong by container ship can increase by only 3 percent.

The rates for the inland modes were more stable. The container-on-barge mode could increase by 76 percent before it would drop out of the solution which emphasizes this mode's competitiveness. The container-on-rail rate between East Grand Forks and Houston can increase by 70 percent before changes in the volume of potatoes transported by this mode would occur. The competitiveness of container-on-rail shipping may be altered by the railroad charging the shipper for the delivery of empty containers. The rate for a long, inland trip such as this one could be particularly affected. The sensitivity analysis suggests that if the additional cost of delivery was 12 cents per hundredweight or less, the container-on-rail mode would remain in use. Any increase above this would eliminate the activity from the solution and a more cost-efficient alternative would be substituted.

Total Transportation Costs and Savings with Container-on-Barge — The total base costs for the production and processing of potatoes for dehydration and the transporting of these products to domestic and foreign markets was $183,780,671. Costs to produce the potatoes comprised 55 percent of the total. Processing costs accounted for 34 percent, and the transportation portion was 11 percent.

The base model was run without including the container-on-barge mode to determine the cost savings that river transportation provides to Northwest shippers. The total cost without container-on-barge shipping was $184,131,203. The costs of production, processing and domestic transportation remained the same, but the cost of shipping exports from origin to ports increased by 83 percent over the base model. The cost of shipping from ports to overseas destinations increased by approximately 1 percent. Table 13 summarizes this information.

B. Fresh Potatoes

Origin to Port by Mode — The lowest-cost exporting system for fresh potatoes was outlined in the base period and forecasting models. Table 14 presents information on the quantities of potatoes shipped from origin to port destinations as well as

Table 11. Processed potato projections: U.S. port to overseas destination by mode.

Destination		Base model[1]	1985 projection	1990 projection	1995 projection	2000 projection
	Port origin	Houston	Houston	Houston	Houston	Houston
Puerto Cabello	Quantity[2]	148	148	148	148	148
	Mode	Container ship	Container ship	Container ship	Container ship	Container ship
	Port origin	Portland	Portland	Portland	Portland	Portland
Rotterdam	Quantity	2,116	2,192	2,268	2,345	2,421
	Mode	Container ship	Container ship	Container ship	Container ship	Container ship
	Port origin	Portland	Portland	Portland	Portland	Portland
Naples	Quantity	100	100	100	100	100
	Mode	Container ship	Container ship	Container ship	Container ship	Container ship
	Port origin	Portland	Portland	Portland	Portland	Portland
Hong Kong	Quantity	1,170	1,240	1,310	1,381	1,451
	Mode	Container ship	Container ship	Container ship	Container ship	Container ship

[1]The base model, representing the present time period, was comprised of data averaged from 1971-78.
[2]Quantities are in 1,000 cwt fwe (fresh-weight-equivalency).

Table 12. Sensitivity analysis of exporting activities in processed potato solution.

Activities in solution of base model				Range in rates			
Origin	Mode	Destination	Actual Rate[1]	Low	% change	High	% change
			($/cwt)				
Tri-Cities	Breakbulk rail	Vancouver, B.C.	$0.203	0	100	0.467	130
Tri-Cities	Container truck	Pasco	0	0	0	0.078	--
Tri-Cities	Container barge	Portland	0.103	0	100	0.181	76
East Grand Forks	Container rail	Houston	0.165	0	100	0.281	70
Portland	Container ship	Rotterdam	1.312	0	100	1.312	0
Portland	Container ship	Naples	1.188	0	100	1.188	0
Portland	Container ship	Hong Kong	2.573	2.573	0	2.651	3
Houston	Container ship	Puerto Cabello	0.98	0.75	23	1.096	12

[1]Rates converted to a fresh-weight-equivalency basis.

the modes used. Few changes took place between the optimum distribution in the base model and those in the projections. Portland was never selected as a transshipment port, indicating that the container-on-barge mode was not as competitive as other transportation alternatives. The predominant mode of shipping used was breakbulk truck.

Table 13. Total production, processing and transportation costs for processed potatoes in base model, per cwt.[1]

	Base hinterland model	Base model without container-barge
Cost of production[2]	$100,380,920	$100,380,920
Percent of total	54.6	54.5
Cost of processing[2]	$63,306,130	$63,306,130
Percent of total	34.4	34.4
Cost of transportation from:		
1. Origin to U.S. destinations	$13,670,001	$13,670,001
Percent of total	68.0	66.9
2. Origin to transshipment ports	$373,178	$683,930
Percent of total	1.9	3.3
3. Port to overseas destinations	$6,050,442	$6,090,222
Percent of total	30.1	29.8
Total transportation cost	$20,093,621	$20,444,153
Percent of total	10.9	11.1
Total production, processing and transportation costs	$183,780,671	$184,131,203

[1]On a fresh-weight-equivalency.

[2]Only costs for production and processing of potatoes that are marketed are computed in the objective function. Surplus production is not included.

Idaho Falls was projected to supply the majority of overseas exports from the Northwest. The container-on-rail mode was selected as the most cost-effective method of transporting these shipments. The other market for Idaho potatoes was Vancouver, British Columbia.

Because of the distance between Idaho Falls and Seattle or Portland, Northwest ports don't necessarily have a locational advantage over other Pacific Coast ports for exporting Idaho potatoes. The rail mode tends to be used more predominantly for longer shipping routes; thus, these exports could as easily be terminated at more southerly Pacific ports. The viability of the container-on-rail mode for long, inland shipments such as these depends a great deal on whether the shipper or the carrier bears the cost of delivery and handling of containers. Our models assumed the carrier absorbed this cost.

Practically all of the supplies on hand at Moses Lake were shipped to British Columbia. A slight 1 percent was transported to Seattle in the early periods to fulfill overseas demand. All shipments from Moses Lake used conventional breakbulk shipping. These results again emphasize that the Moses Lake area is a natural hinterland for the port of Seattle.

Destination from U.S. Port by Mode — The ocean leg of the exporting system was delineated in the models and is represented in Table 15. The European destination of Rotterdam was supplied com-

Table 14. Fresh potato projections: origin to port destination by mode.

Model alternatives	Idaho Falls			Moses Lake			East Grand Forks		
	Ocean port	Quantity	Mode[1]	Ocean port	Quantity	Mode[1]	Ocean port	Quantity	Mode[1]
		(1,000 cwt)			(1,000 cwt)			(1,000 cwt)	
Base model[2]	Seattle Vancouver, B.C.[3]	1,066 100	C. rail BB. truck	Seattle Vancouver, B.C.[3]	44 3,378	BB. truck BB. truck	Vancouver, B.C.	523	BB. truck
Total		1,166			3,422			523[4]	
1985 projection	Seattle Vancouver, B.C	1,066 100	C. rail BB. truck	Seattle Vancouver, B.C.	46 3,376	BB. truck BB. truck	Vancouver, B.C.	525	BB. truck
Total		1,166			3,422			525	
1990 projection	Seattle Vancouver, B.C	1,114 52	C. rail BB. truck	Vancouver, B.C.	3,422	BB. truck	Vancouver, B.C.	527	BB. truck
Total		1,166			3,422			530	
1995 projection	Seattle Vancouver, B.C.	1,117 49	C. rail BB. truck	Vancouver, B.C	3,422	BB. truck	Vancouver, B.C.	530	BB truck
Total		1,166			3,422			48	
2000 projection	Seattle Vancouver, B.C.	635 531	C. rail BB. rail	Vancouver, B.C	3,422	BB. truck	Vancouver, B.C.	48	BB. truck
Total		1,166			3,422			48	

[1]BB. truck = breakbulk truck, BB rail = breakbulk rail, C. rail = container rail.

[2]The base model was comprised of data averaged from 1971-78. It is representative of the present time period.

[3]Vancouver, B.C., and Mexico are actually final destinations rather than transshipment points.

pletely from the port of Seattle in all but the year 2000. In that year, New York was projected to supply 45 percent of Rotterdam's potatoes while Seattle's share decreased to 55 percent. Seattle was projected to fulfill all of the Asian demand at the Hong Kong basing point. The ports of New York and Portland, Maine, through various combinations of shipments, supplied all exports to the Caribbean destination (Santo Domingo), the Latin America basing point (Buenos Aires) and the Mediterranean destination (Naples).

The ocean mode which served the largest number of routes in the projections was breakbulk vessel. The ocean mode that carried the largest quantities of potatoes was container vessel.

An interesting shift in port shares occurred between the base period and the year 2000. Originally, Seattle was projected as the port origin for 63 percent of total exports, New York as the origin for 28 percent and Portland, Maine, for 9 percent. In the final period, Seattle's share had decreased to 36 percent while New York's had increased to 36 percent and the share from Portland, Maine, had risen to 28 percent. The increasing fuel costs for the inland modes seemed to provide the impetus for this shift. As the rate for truck transportation increased more severely than for rail because of efficient use of fuel by the latter, the level of shipments from Idaho Falls to Seattle was curtailed. Rail shipments from Idaho Falls to Canada were substituted for more costly truck shipments from East Grand Forks. Other adjustments resulted in the higher levels of export from Portland, Maine, and New York City ports.

Sensitivity Analysis — Table 16 shows the transportation rates sensitivity in the base model for fresh potatoes. Sensitivity analysis portrays the amount a single rate can vary before the optimal mix of activities in the solution is changed, assuming all other rates remain static. The modes are highly sensitive to increases in their rates, indicating that the solution's variables could change substantially with only slight increases in transportation charges. The ocean modes were the most acutely sensitive, with increases of less than 1 percent causing changes in the levels of these activities. Inland modes were highly sensitive as well. The container-on-rail rate between Idaho Falls and Seattle could increase by only 5 percent before it would be eliminated and an alternative mode selected.

Total Transportation Costs — The total base costs for producing and packaging fresh potatoes for shipment and transporting these potatoes to foreign destinations were $59,416,220. The cost of production contributed 30 percent to the total, the cost of packaging 21 percent and the cost of transportation 49 percent. The cost of shipping fresh potatoes from origin to transshipment port accounted for 31 percent of the overall transportation charge while the costs from port to overseas destination contributed 69 percent. This information is shown in Table 17. Since Columbia/Snake river transportation was not a part of the least-cost distribution system, container-on-barge shipping offered no savings to exporters of fresh potatoes.

Table 14. (continued).

Model alternatives	Alamosa: Ocean port	Alamosa: Quantity	Alamosa: Mode[1]	Presque Isle: Ocean port	Presque Isle: Quantity	Presque Isle: Mode[1]	Long Island: Ocean port	Long Island: Quantity	Long Island: Mode[1]
		(1,000 cwt)			(1,000 cwt)			(1,000 cwt)	
Base model	Mexico[3]	219	BB. truck	Portland, Maine	166	BB. truck	New York	484	BB. truck
Total		219[5]			166[6]			484	
1985 projection	Mexico	219	BB. truck	Portland, Maine	166	BB. truck	New York	484	BB. truck
Total		219			166			484	
1990 projection	Mexico	219	BB. truck	Portland, Maine	166	BB. truck	New York	484	BB. truck
Total		219			166			484	
1995 projection	Mexico	219	BB. truck	Portland, Maine	166	BB. truck	New York	484	BB truck
Total		219			166			484	
2000 projection	Mexico	219	BB. truck	Portland, Maine	650	BB truck	New York	484	C. truck
Total		219			650			484	

[4]An untransported surplus accumulated at East Grand Forks in each model. The surplus was 2,915 units in the base. 2,913 units in the 1985 projection, 2,911 units in 1990, 2,908 in 1995 and 3,390 in 2000

[5]An untransported surplus of 2,715 units accumulated at Alamosa in each model

[6]An untransported surplus accumulated at Presque Isle in each model. The surplus was 4,009 units from the base period through 1995 and 3,525 units in 2000.

Table 15. Fresh potato projections: U.S. port to overseas destination by mode.

Destination		Base model[1]	1985 projection	1990 projection	1995 projection	2000 projection
Santo Domingo	Port origin	New York	New York	New York	New York	New York
	Quantity[2]	149	149	149	149	149
	Mode	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship
Buenos Aires	Port origin	New York	New York	New York	Portland, Maine	Portland, Maine
	Quantity	133	133	133	133	133
	Mode	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship
Rotterdam	Port origin	Seattle	Seattle	Seattle	Seattle	Seattle
	Quantity	1,066	1,066	1,066	1,066	582
	Mode	Container ship	Container ship	Container ship	Container ship	Container ship
	Port origin					New York
	Quantity					484
	Mode					Container ship
Naples	Port origin	Portland, Maine	Portland, Maine	Portland, Maine	Portland, Maine	Portland, Maine
	Quantity	166	166	165	33	368
	Mode	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship
	Port origin	New York	New York	New York	New York	
	Quantity	202	202	202	335	
	Mode	Breakbulk ship	Breakbulk ship	Breakbulk ship	Breakbulk ship	
Hong Kong	Port origin	Seattle	Seattle	Seattle	Seattle	Seattle
	Quantity	44	46	48	51	53
	Mode	Breakbulk ship	Breakbulk ship	Container ship	Container ship	Container ship

[1]The base model, representing the present time period, was comprised of data averaged from 1971-78.

[2]Quantities are in 1,000 cwt.

Table 16. Sensitivity analysis of transportation rates in fresh potato solution.

Activities in solution of base model				Range in rates			
Origin	Mode	Destination	Actual rate	Low	% change	High	% change
			($/cwt)				
Idaho Falls	Container rail	Seattle	$1.94	1.93	0.5	2.04	5
Idaho Falls	Breakbulk truck	Vancouver, B.C.	2.10	1.75	17	2.11	0.5
Moses Lake	Breakbulk truck	Seattle	0.70	0.33	53	0.74	6
Moses Lake	Breakbulk truck	Vancouver, B.C.	1.10	1.06	4	1.45	32
East Grand Forks	Breakbulk truck	Vancouver, B.C.	3.56	3.55	0.3	3.82	7
Alamosa	Breakbulk truck	Mexico[1]	2.35	0	100	3.21	37
Presque Isle	Breakbulk truck	Portland, Maine	1.10	0.66	40	1.11	0.9
Long Island	Breakbulk truck	New York	0.70	0	100	0.75	7
Seattle	Container ship	Rotterdam	11.88	0	100	11.98	0.8
Seattle	Breakbulk ship	Hong Kong	11.44	11.07	3	11.48	0.3
Portland, Maine	Breakbulk ship	Naples	14.89	14.45	3	14.89	0
New York	Breakbulk ship	Santo Domingo	6.13	0	100	6.13	0
New York	Breakbulk ship	Buenos Aires	5.69	0	100	5.69	0
New York	Breakbulk ship	Naples	14.07	14.02	0.4	14.07	0

[1]Transportation rates to Mexico were not available. Cost of shipping was approximated using Brownsville, Texas, as a representative point.

Table 17. Total production, processing and transportation costs for fresh potatoes in base model, per cwt.

	Base hinterland model
Cost of production[1]	$17,865,320
Percent of total	30.1
Cost of processing[1]	$12,476,870
Percent of total	21.0

		Base hinterland model
Cost of transportation from:		
1. Origin to transshipment port	$8,922,570	
% of total	30.7	
2. Port to overseas destination	$20,151,460	
% of total	69.3	
Total transportation cost	$29,074,030	
Percent of total		48.9
Total production, processing and transportation costs		$59,416,220

[1]Only costs for production and processing of potatoes that are marketed are computed in the objective function. Surplus production is not included.

Conclusions and Implications

This report analyzed the existing and potential export marketing systems for fresh and processed potatoes. Transshipment models representative of national production regions were used. Estimates of changes in supply and demand were incorporated into projections of exports over the next 20 years. Probable use of the Columbia/Snake waterway was examined along with which ocean ports will serve as export points.

Extensive data requirements are associated with these linear programs. Information on production, use, domestic consumption, foreign demand, marketing and transportation costs and shipping practices were assembled and tabulated. These inputs emerged in the base hinterland models as the least-cost solutions to potato exporting.

Total Marketing Costs

The transportation costs projected in the forecasts increased slightly from the base period. Costs of distribution of processed potatoes were projected to increase by 9 percent in the year 2000 while costs for fresh potatoes increased by only 3 percent.

Container-on-barge shipping slightly decreased total costs for exporting dehydrated potatoes in the models — only a 0.2 percent reduction — but the container-on-barge mode was projected to capture approximately 40 percent of shipments. Exporters of fresh potatoes were located too distant from the waterway to use its services economically.

Sensitivity analysis suggested that many of the transportation modes were near their upper range of stability. In the competitive pricing environment of carriers, only slight changes in rates will substantially redistribute shipments among alternate modes of transportation. The energy component of the inland transportation rates was increased by 25, 50, 100 and 150 percent for the forecasts; all other prices held constant. The selection of inland mode was not greatly influenced by these increases. The modes brought into the solution of the base hinterland projections were the most cost efficient for a given route. Their consistency of selection in the forecasts would indicate that they are also the most fuel efficient for a given cost.

Container-on-Barge: Study Implications

The container-on-barge mode was projected to find greatest use with processed potatoes. Container-on-barge was not selected for transporting fresh potatoes. Approximately 40 percent of dehydrated shipments travelled by barge in the forecasts. Although the overall savings in marketing costs provided by Columbia/Snake river transportation was negligible, the decreased costs to the Washington-Oregon production region were projected to be quite high. An 83 percent increase in the costs of shipping dehydrated potatoes from origin to transshipment port occurred when the container-on-barge mode was excluded from the model.

Hinterland Delineation: Study Implications

Results of the transshipment model indicate that Portland is the least-cost ocean port for processed potato exports, and Seattle is the least-cost ocean port for fresh potato exports. Middle Columbia area ports were projected as the least-cost river terminals for container-on-barge shipping. The economic hinterland for the Columbia Snake river, and by extension Portland and other downriver ocean ports, is limited to shippers who are adjacent or near the waterway. These shippers will have an advantage for using the container-on-barge mode for their exports. Generally, the Middle Columbia was projected as a user area for container-on-barge shipments while the Upper Columbia was not.

Export Projections

The transshipment models were used to forecast probable levels of potato exports in the future and to identify the portion of these exports that might economically use container-on-barge shipping. Moderate increases in demand for imports of dehydrated products were projected over the period. Only very slight increases were forecast for fresh potatoes. The container-on-barge mode was not chosen as a least-cost transportation alternative for fresh potatoes, but it was consistently selected as an economical method of shipping processed products downriver to Portland for export.

Cargo projections of dehydrated potatoes on the Columbia/Snake river system were forecast as 564,333 cwt in the base hinterland model, 588,667 cwt in 1985, 613,000 cwt in 1990, 637,667 cwt in 1995 and 622,000 cwt in the year 2000 (on an actual product weight equivalency). These projections may overstate the actual potential for container-on-barge shipping of processed potatoes to the extent that Upper Columbia Basin processors are not fully represented by the Tri-Cities production origin. Shipping conditions in the Moses Lake area may dictate different transportation economies than in the Lower Columbia. However, confidentiality of information concerning supplies in the region necessitated aggregation of data into single, representative points. Models with greater disaggregation would more fully describe the physical export system available to individual shippers within the Northwest.

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Appendix A

Baseline Activities — Fresh Potato Model: Routes, Modes and Rates.

Activity	Mode[1]	Rate (T_{ijk}) per cwt
Idaho Falls to Lewiston	C. truck	$ 4.01
Idaho Falls to Lewiston	C. rail	2.70
Idaho Falls to Pasco	C. truck	4.18
Idaho Falls to Pasco	C. rail	3.47
Idaho Falls to Umatilla	C. truck	3.82
Idaho Falls to Umatilla	C. rail	3.69
Idaho Falls to Portland	BB. truck	1.75
Idaho Falls to Portland	C. truck	5.13
Idaho Falls to Portland	BB. rail	2.16
Idaho Falls to Portland	C. rail	2.04
Idaho Falls to Seattle	BB. truck	2.25
Idaho Falls to Seattle	C. truck	5.81
Idaho Falls to Seattle	BB. rail	2.16
Idaho Falls to Seattle	C. rail	1.94
Idaho Falls to New York	BB. truck	4.89
Idaho Falls to New York	BB. rail	4.77
Idaho Falls to Vancouver, Canada	BB. truck	2.10
Idaho Falls to Vancouver, Canada	BB. rail	2.28
Idaho Falls to Mexico City, Mexico[2]	BB. truck	4.19
Idaho Falls to Mexico City, Mexico[2]	BB. rail	4.10
Moses Lake to Pasco	C. truck	0.52
Moses Lake to Pasco	C. rail	5.27
Moses Lake to Umatilla	C. truck	0.85
Moses Lake to Umatilla	C. rail	5.46
Moses Lake to Portland	BB. truck	0.80
Moses Lake to Portland	C. truck	2.02
Moses Lake to Portland	BB. rail	1.89
Moses Lake to Portland	C. rail	3.66
Moses Lake to Seattle	BB. truck	0.70
Moses Lake to Seattle	C. truck	1.29
Moses Lake to Seattle	BB. rail	1.89
Moses Lake to Seattle	C. rail	3.66
Moses Lake to New York	BB. truck	5.60
Moses Lake to New York	BB. rail	5.12
Moses Lake to Vancouver, Canada	BB. truck	1.10
Moses Lake to Vancouver, Canada	BB. rail	2.07
Moses Lake to Mexico City, Mexico[2]	BB. truck	4.96
Moses Lake to Mexico City, Mexico[2]	BB. rail	4.47
E. Grand Forks to Portland	BB. truck	3.42
E. Grand Forks to Portland	BB. rail	3.88
E. Grand Forks to Seattle	BB. truck	3.65
E. Grand Forks to Seattle	BB. rail	3.91
E. Grand Forks to New York	BB. truck	4.10
E. Grand Forks to New York	BB. rail	3.65
E. Grand Forks to Vancouver, B.C.	BB. truck	3.51
E. Grand Forks to Vancouver, B.C.	BB. rail	4.08
E. Grand Forks to Mexico City, Mex.[2]	BB. truck	3.56
E. Grand Forks to Mexico City, Mex.[2]	BB. rail	4.08
Alamosa to Portland	BB. truck	3.25
Alamosa to Portland	BB. rail	3.53
Alamosa to Seattle	BB. truck	3.42
Alamosa to Seattle	BB. rail	3.75
Alamosa to New York	BB. truck	5.00

C. truck = container on truck; BB. truck = breakbulk truck; C. rail = container on rail; BB. rail = breakbulk rail; C. barge = container on barge; C. ship = container ship; BB. ship = breakbulk ship.

Activity	Mode[1]	Rate (T_{ijk}) per cwt
Alamosa to New York	BB. rail	4.20
Alamosa to Vancouver, Canada	BB. truck	3.68
Alamosa to Vancouver, Canada	BB. rail	3.93
Alamosa to Mexico City, Mexico[2]	BB. truck	2.35
Alamosa to Mexico City, Mexico[2]	BB. rail	3.80
Presque Isle to Portland, Maine	BB. truck	$ 1.10
Presque Isle to New York	BB. truck	2.05
Presque Isle to New York	C. truck	4.62
Long Island to New York	BB. truck	0.70
Long Island to New York	C. truck	0.75
Long Island to New York	BB. rail	1.80
Long Island to New York	C. rail	5.69
Lewiston to Portland[3]	C. barge	1.22
Pasco to Portland[3]	C. barge	1.04
Umatilla to Portland[3]	C. barge	1.04
Portland to Santo Domingo	C. ship	12.68
Portland to Buenos Aires	BB. ship	16.82
Portland to Buenos Aires	C. ship	15.74
Portland to Rotterdam	BB. ship	12.49
Portland to Rotterdam	C. ship	11.88
Portland to Naples	BB. ship	12.79
Portland to Naples	C. ship	12.17
Portland to Hong Kong	BB. ship	11.44
Portland to Hong Kong	C. ship	11.24
Seattle to Santo Domingo	C. ship	12.68
Seattle to Buenos Aires	BB. ship	16.82
Seattle to Buenos Aires	C. ship	15.74
Seattle to Rotterdam	BB. ship	12.49
Seattle to Rotterdam	C. ship	11.88
Seattle to Naples	BB. ship	12.79
Seattle to Naples	C. ship	12.17
Seattle to Hong Kong	BB. ship	11.44
Seattle to Hong Kong	C. ship	11.24
New York to Santo Domingo	BB. ship	6.13
New York to Santo Domingo	C. ship	6.13
New York to Buenos Aires	BB. ship	5.69
New York to Buenos Aires	C. ship	5.69
New York to Rotterdam	BB. ship	15.40
New York to Rotterdam	C. ship	14.23
New York to Naples	BB. ship	14.07
New York to Naples	C. ship	14.07
New York to Hong Kong	BB. ship	35.53
New York to Hong Kong	C. ship	35.53
Portland, Maine to Santo Domingo	BB. ship	6.95
Portland, Maine to Buenos Aires	BB. ship	6.51
Portland, Maine to Rotterdam	BB. ship	16.22
Portland, Maine to Naples	BB. ship	14.89
Portland, Maine to Hong Kong	BB. ship	36.53

[2]Transportation rates to Mexico City were not available. Cost of shipping to Mexico City was approximated using Brownsville, Texas, as a representative point.

[3]Container-on-barge rates for fresh potatoes were estimated by doubling the charges for shipping dried potatoes. There is no refrigerated barge service on the Columbia Snake river system at present, so no rates were available.

Appendix B

Baseline Activities — Processed Potato Model: Routes, Modes and Rates.

Activity	Mode[1]	Rate (T_{ijk}) per cwt, fwe[2]
Idaho Falls to Sacramento	BB. truck	$0.708
Idaho Falls to Sacramento	BB. rail	0.288
Idaho Falls to Denver	BB. truck	0.818
Idaho Falls to Denver	BB. rail	0.443
Idaho Falls to Chicago	BB. truck	1.132
Idaho Falls to Chicago	BB. rail	0.488
Idaho Falls to Dallas	BB. truck	1.107
Idaho Falls to Dallas	BB. rail	0.563
Idaho Falls to Atlanta	BB. truck	1.380
Idaho Falls to Atlanta	BB. rail	0.858
Idaho Falls to New York	BB. truck	1.540
Idaho Falls to New York	BB. rail	0.932
Idaho Falls to Vancouver, Canada	BB. truck	1.070
Idaho Falls to Vancouver, Canada	BB. rail	0.447
Idaho Falls to Lewiston	C. truck	0.472
Idaho Falls to Lewiston	C. rail	0.317
Idaho Falls to Pasco	C. truck	0.497
Idaho Falls to Pasco	C. rail	0.333
Idaho Falls to Umatilla	C. truck	0.455
Idaho Falls to Umatilla	C. rail	0.340
Idaho Falls to Portland	BB. truck	0.653
Idaho Falls to Portland	C. truck	0.587
Idaho Falls to Portland	BB. rail	0.293
Idaho Falls to Portland	C. rail	0.278
Idaho Falls to Seattle	BB. truck	0.675
Idaho Falls to Seattle	C. truck	0.657
Idaho Falls to Seattle	BB. rail	0.325
Idaho Falls to Seattle	C. rail	0.295
Idaho Falls to Bay Area	BB. truck	0.708
Idaho Falls to Bay Area	C. truck	0.717
Idaho Falls to Bay Area	BB. rail	0.288
Idaho Falls to Bay Area	C. rail	0.250
Idaho Falls to Houston	BB. truck	0.930
Idaho Falls to Houston	BB. rail	0.593
Idaho Falls to Norfolk	BB. truck	1.470
Idaho Falls to Norfolk	BB. rail	0.932
Tri-Cities to Sacramento	BB. truck	0.764
Tri-Cities to Sacramento	BB. rail	0.308
Tri-Cities to Denver	BB. truck	0.927
Tri-Cities to Denver	BB. rail	0.413
Tri-Cities to Chicago	BB. truck	1.262
Tri-Cities to Chicago	BB. rail	0.678
Tri-Cities to Dallas	BB. truck	1.221
Tri-Cities to Dallas	BB. rail	0.667
Tri-Cities to Atlanta	BB. truck	1.486
Tri-Cities to Atlanta	BB. rail	0.797
Tri-Cities to New York	BB. truck	1.559
Tri-Cities to New York	BB. rail	0.953
Tri-Cities to Vancouver, Canada	BB. truck	0.604
Tri-Cities to Vancouver, Canada	BB. rail	0.203
Tri-Cities to Pasco	C. truck	0.0
Tri-Cities to Umatilla	C. truck	0.083
Tri-Cities to Portland	BB. truck	0.544
Tri-Cities to Portland	C. truck	0.222
Tri-Cities to Portland	BB. rail	0.147
Tri-Cities to Portland	C. rail	0.350
Tri-Cities to Seattle	BB. truck	0.544
Tri-Cities to Seattle	C. truck	0.22
Tri-Cities to Seattle	BB. rail	0.157
Tri-Cities to Seattle	C. rail	0.347
Tri-Cities to Bay Area	BB. truck	0.793
Tri-Cities to Bay Area	C. truck	0.708
Tri-Cities to Bay Area	BB. rail	0.365
Tri-Cities to Bay Area	C. rail	0.257
Tri-Cities to Houston	BB. truck	1.297
Tri-Cities to Houston	Bb. rail	0.747
Tri-Cities to Norfolk	BB. truck	1.654
Tri-Cities to Norfolk	BB. rail	0.94
E. Grand Forks to Denver	BB. truck	0.753
E. Grand Forks to Denver	BB. rail	0.335
E. Grand Forks to Chicago	BB. truck	0.573
E. Grand Forks to Chicago	BB. rail	0.273
E. Grand Forks to Dallas	BB. truck	1.062
E. Grand Forks to Dallas	BB. rail	0.383
E. Grand Forks to Atlanta	BB. truck	1.028
E. Grand Forks to Atlanta	BB. rail	0.405
E. Grand Forks to New York	BB. truck	1.108
E. Grand Forks to New York	BB. rail	0.490
E. Grand Forks to Vancouver. B.C.	BB. truck	1.108
E. Grand Forks to Vancouver. B.C.	BB. rail	0.605
E. Grand Forks to Houston	BB. truck	1.200
E. Grand Forks to Houston	C. truck	1.320
E. Grand Forks to Houston	BB. rail	0.458
E. Grand Forks to Houston	C. rail	0.165
Presque Isle to Chicago	BB. truck	0.800
Presque Isle to Chicago	BB. rail	0.497
Presque Isle to Atlanta	BB. truck	0.982
Presque Isle to Atlanta	BB. rail	0.560
Presque Isle to New York	BB. truck	0.503
Presque Isle to New York	BB. rail	0.300
Presque Isle to Norfolk	BB. truck	0.830
Presque Isle to Norfolk	C. truck	0.870
Presque Isle to Norfolk	BB. rail	0.435
Presque Isle to Norfolk	C. rail	0.227

[1]C. truck = container on truck; BB. truck = breakbulk truck; C. rail = container on rail; BB. rail = breakbulk rail; C. barge = container barge; C. ship = container ship; BB. ship = breakbulk ship.

[2]Rates were converted to a fresh-weight-equivalency.

Appendix B (cont'd).

Activity	Mode[1]	Rate (T_{ijk}) per cwt, fwe[2]
Lewiston to Portland	C. barge	0.117
Pasco to Portland	C. barge	0.103
Umatilla to Portland	C. barge	0.103
Portland to Puerto Cabello	BB. ship	3.077
Portland to Puerto Cabello	C. ship	2.957
Portland to Rotterdam	BB. ship	1.715
Portland to Rotterdam	C. ship	1.312
Portland to Naples	BB. ship	1.550
Portland to Naples	C. ship	1.188
Portland to Hong Kong	BB. ship	2.607
Portland to Hong Kong	C. ship	2.573
Seattle to Puerto Cabello	BB. ship	3.077
Seattle to Puerto Cabello	C. ship	2.957
Seattle to Rotterdam	BB. ship	1.715
Seattle to Rotterdam	C. ship	1.312
Seattle to Naples	BB. ship	1.550
Seattle to Naples	C. ship	1.188
Seattle to Hong Kong	BB. ship	2.607
Seattle to Hong Kong	C. ship	2.573
Bay Area to Puerto Cabello	BB. ship	3.077
Bay Area to Puerto Cabello	C. ship	2.957
Bay Area to Rotterdam	BB. ship	1.715
Bay Area to Rotterdam	C. ship	1.312
Bay Area to Naples	BB ship	1.550
Bay Area to Naples	C ship	1.188
Bay Area to Hong Kong	BB. ship	2.607
Bay Area to Hong Kong	C ship	2.573
Houston to Puerto Cabello	BB. ship	1.110
Houston to Puerto Cabello	C. ship	0.980
Houston to Rotterdam	BB. ship	1.148
Houston to Rotterdam	C. ship	1.018
Houston to Naples	BB ship	1.728
Houston to Naples	C. ship	1.598
Houston to Hong Kong	BB. ship	3.905
Houston to Hong Kong	C. ship	3.708
Norfolk to Puerto Cabello	BB ship	0.960
Norfolk to Puerto Cabello	C. ship	0.960
Norfolk to Rotterdam	BB. ship	2.558
Norfolk to Rotterdam	C. ship	2.363
Norfolk to Naples	BB. ship	1.287
Norfolk to Naples	C. ship	1.287
Norfolk to Hong Kong	BB ship	3.755
Norfolk to Hong Kong	C. ship	3.708

[1]C. truck = container on truck; BB. truck = breakbulk truck; C. rail = container on rail; BB. rail = breakbulk rail; C barge = container on barge; C. ship = container ship; BB. ship = breakbulk ship.
[2]Rates were converted to a fresh-weight-equivalency.

Appendix C

Projections of Increases in Demand for Processed Potatoes Based on Income Elasticities

The elasticity of income is mathematically defined as:

$$E_y = \frac{\%\Delta Q}{\%\Delta Y}$$

where E_y = income elasticity
Q = quantity demanded
Y = income

1. Measures of income elasticities (E_y):
   A high measure of 0.2539 for demand of all potato products in the U.S. (O'Rourke 1980), and a low measure of 0.1006 for demand of instant mashed potatoes in Canada (Hassan 1977) were used in the projections.

2. Projections of changes in income (ΔY):
   A 5% annual average growth rate in real GNP was estimated to occur in Asia from 1978-90, and a 3% rate was projected for Europe (Exxon Corporation 1979).

3. Equations:

Region	High Range	Low Range
Asia	$0.2539 = \frac{\%\Delta Q}{.05}$	$0.1006 = \frac{\%\Delta Q}{.05}$
	$\Delta Q = 1.27\%$	$\Delta Q = 0.503\%$
Europe	$0.2539 = \frac{\%\Delta Q}{.03}$	$0.1006 = \frac{\%\Delta Q}{.03}$
	$\Delta Q = 0.762\%$	$\Delta Q = 0.302\%$

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