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Spatial Equilibrium Analysis of the World Durum Industry Under Alternative Export Policies

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Highlights

A static spatial programming model was used to evaluate international competition among the United States, Canada, and several countries of the European Community in the production and export of durum and semolina. The model includes tariffs on durum and semolina traded between the United States and Canada and Canada's import license on durum imports. The model also included export subsidies used by exporting countries: the U.S. Export Enhancement Program (EEP), the EC Export Refund Program (ERP), and the Canadian rail subsidies for shipping durum to export ports under the Western Grain Transportation Act (WGTA).

The objective of the model was to minimize durum production costs at producing regions, distribution costs of durum from producing regions to mills or ports for export, distribution costs of semolina from mills to consumption regions (pasta plants), or ports and distribution costs of durum and semolina from ports to importing countries. The objective function was optimized subject to the following constraints: 1) lower and upper limits on land acreage planted to durum, 2) equilibrium condition for each producing region, 3) demand for semolina in each consuming region (pasta plant), 4) import demand for durum in each importing country, 5) inventory clearing conditions at each mill and port, 6) milling capacity at each mill, and 7) quality conditions for the milling of durum.

This study indicates bilateral trade in durum and semolina between the United States and Canada will increase under the free trade agreement. Canada will still have a trade surplus with the removal of its import license. Increased bilateral trade will increase production especially in North Dakota and Alberta. Production in North Dakota increases under free trade because of the state's low production costs. Production in Alberta increases because its far west location gives it a competitive advantage in supplying durum to the large western market in the United States.

The majority of Canadian exports to the western United States come from a durum mill in Alberta. This mill along with mills in North Dakota, Montana, and Arizona are the most competitive mills in the United States and Canada. These regions may increase capacity under free trade, while French production and exports may decrease.

Export subsidies used by the United States, Canada, and EC play an important role in the world durum market. The United States and France would lose the most durum production and exports without their subsidy programs. Canada's overall production and exports would decrease.

World free trade increases durum production in the United States, has little impact on Canada, and decreases French durum production. France cannot compete with the United States due to higher production costs. U.S. exports increase, while French exports decrease.

Spatial Equilibrium Analysis of the World Durum Industry Under Alternative Export Policies

Introduction

World trade in durum wheat has increased from an average of 1.75 million metric tons (mmt) in the 1960s to 5.51 mmt in 1989/90 (Table 1). The major exporters of durum wheat are the United States, Canada, and the European Community (EC) and account for nearly all durum wheat exports. Canada has been the major exporter of durum throughout the 1980s, followed by the United States and the EC (Table 1). France is the major durum exporter in the EC. These three countries compete in a few highly concentrated import markets, such as Italy, Algeria, Tunisia, USSR, and Venezuela.

Export promotion policies used by exporting countries are the Export Enhancement Program (EEP) used by the United States, the Export Refund Program (ERP) used by France, and rail subsidies under the Western Grain Transportation Act (WGTA) in Canada. They also use tariffs and non-tariff barriers to protect their domestic durum wheat production. EC's variable levy is a typical example of border protection. In addition, the U.S./Canadian Free Trade Agreement (FTA) will alter trade flows of durum between the two countries and also with third world countries. Aggressiveness of the recent EC export promotion program may have attributed to reductions in U.S. exports.

Competitiveness of durum production in exporting countries and trade flows are influenced not only by trade restricting and aiding programs, but also the quality of durum wheat produced in a region, availability of resources used to produce durum in the

TABLE 1. DURUM EXPORTS AND MARKET SHARES FOR CANADA, THE UNITED STATES, AND EUROPEAN COMMUNITY, 1980-1990

	Canada		U.S.		EC		World Total
Crop Year	mmt	%	mmt	%	mmt	%	mmt
1980/81	2.21	53	1.54	37	0.08	2	4.15
1981/82	2.40	50	2.28	47	0.15	3	4.85
1982/83	2.89	61	1.41	32	0.26	6	4.40
1983/84	2.50	61	1.47	36	0.08	2	4.09
1984/85	1.98	56	1.41	40	0.11	3	3.52
1985/86	1.45	43	1.40	42	0.50	15	3.34
1986/87	2.04	48	2.09	49	0.09	2	4.26
1987/88	2.67	48	1.49	27	0.77	14	5.53
1988/89	2.10	42	0.49	10	1.83	37	4.94
1989/90	2.95	54	1.54	28	0.39	7	5.51

SOURCE: Foreign Agriculture Service, 1991.

region, and processing capacity for semolina production. The quality of durum wheat and resource endowments, which mainly are determined by weather and soil types, are treated as exogenous. Durum wheat and semolina production are highly integrated, implying that competitiveness of these two products is assumed to be determined simultaneously. This study, therefore, focuses on competitiveness of durum wheat and semolina production with the given production conditions under alternative trade policies.

The primary objective of this study is to determine the effects of changing trade promotion and restricting programs on international durum trade. Specific objectives are:

1. To evaluate the impact of the U.S.-Canadian Free Trade Agreement (FTA) on durum production, milling, and bilateral trade of durum and semolina between the U.S. and Canada.

2. To analyze the impact of eliminating U.S., Canadian, and EC subsidy programs on durum production, export flows and market shares. The export subsidy programs are the U.S. Export Enhancement Program (EEP), the EC Export Refund Program (ERP), and Canadian rail subsidies under the Western Grain Transportation Act (WGTA).

3. To analyze the impact of world free trade on international competition among the United States, Canada, and the EC in producing and exporting durum.

This study uses a spatial equilibrium model which minimizes production and distribution costs. The trade policy variables included in this study are policies used by exporting countries. Trade restrictions used by importing countries are not included in this study since importing countries apply these trade restrictions to all exporting countries, and thus, would have little impact on trade flows.

Although many studies have evaluated the competitiveness of the U.S. agricultural sector in the world market (Haley and Krissoff, Koo and Drennan, Perkins, Shane, Sharples, Sharples and Milhem, Vollrath) none have focused on trade flows and competitiveness of durum wheat and semolina production in the world market nor did they simultaneously evaluate competitiveness of durum wheat and semolina production.

Durum and Semolina Industries in the United States and Canada

North Dakota produced 1.82 mmt (72 percent) of U.S. durum in 1989 (Table 2). California and Arizona together produced 17 percent and Montana, South Dakota, and Minnesota 11 percent of durum in 1989. Durum production in North Dakota is concentrated in the northern part of the state. The three northern Crop

TABLE 2. UNITED STATES DURUM PRODUCTION BY MAJOR PRODUCING STATES, MILLION METRIC TONS, 1980-1989

State	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
ND	1.82	0.85	2.02	2.18	2.61	2.14	1.48	3.03	1.99	3.49
SD	0.08	0.02	0.08	0.04	0.07	0.09	0.06	0.10	0.16	0.11
MN	0.03	0.02	0.03	0.04	0.05	0.04	0.03	0.08	0.15	0.09
MT	0.18	0.06	0.15	0.12	0.04	0.10	0.11	0.28	0.30	0.21
CA	0.24	0.15	0.14	0.18	0.20	0.26	0.32	0.40	0.40	0.21
AZ	0.21	0.12	0.10	0.12	0.11	0.20	0.14	0.19	0.50	0.34
U.S.	**2.56**	**1.22**	**2.53**	**2.67**	**3.08**	**2.81**	**2.14**	**4.08**	**3.50**	**4.45**

SOURCE: USDA, National Agricultural Statistics Service, 1991.

Reporting Districts of North Dakota produced 70 percent of the state's total durum from 1984 to 1988.

Montana which produces 5 percent of U.S. durum, has two major producing regions located in the north central and northeastern parts of the state. South Dakota's durum production of 3 percent is concentrated in the northeastern part of the state. Western Minnesota produces most of the state's durum but its production has been decreasing steadily since 1980 and was just 1 percent of U.S. production in 1989. Durum grown in California and Arizona is planted in the fall and can be harvested before durum is harvested in the midwest. California has produced the majority of the durum grown in the southwest. The quality of durum produced in the United States is to some extent, influenced by the government programs. Government programs in the United States tend to favor yield over quality. Durum variety development programs have emphasized developing high gluten durum that is ideal for pasta products, thus sacrificing larger yield increases for quality. Variety development for other classes of wheat such as spring wheat has resulted in relatively higher yield. This may bias producer decisions toward planting higher yielding classes of wheat.

Canadian durum production is concentrated in southern Saskatchewan with the rest being produced in southwestern Manitoba and southeastern Alberta. In 1989, Saskatchewan produced 74 percent of Canada's durum, Alberta 20 percent, and Manitoba 6 percent (Table 3). The primary region of durum production in Saskatchewan lies directly north and northwest of the major durum producing area in North Dakota.

Canada's increased durum production since 1980, combined with low per capita consumption of pasta and a smaller population base than the United States, has increased their efforts of

TABLE 3. CANADIAN DURUM PRODUCTION BY MAJOR PRODUCING PROVINCES, MILLION METRIC TONS, 1980-1989

Province	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Sask.	306	1.36	3.08	2.97	1.39	1.64	2.07	2.56	2.29	1.69
Alberta	0.82	0.49	0.68	0.56	0.25	0.29	0.41	0.38	0.50	0.27
Manitoba	0.24	0.13	0.26	0.37	0.33	0.19	0.15	0.18	0.20	0.08
Canada	**4.12**	**1.98**	**4.02**	**3.90**	**1.97**	**2.12**	**2.63**	**3.12**	**2.99**	**2.04**

SOURCE: Canadian Wheat Board, 1991.

export sales so, which account for 70 percent of Canadian durum disappearance.

Pasta consumption in the United States has grown from 10 pounds per capita in 1980 to 18.5 pounds per capita in 1990. Although pasta consumption has increased throughout the United States consumption is concentrated in the northeast among Italian immigrants (National Pasta Association). The growth of pasta consumption can be attributed to its low fat and complex carbohydrates, convenience, low price, and a stepped-up promotional campaign.

A hundred pounds of durum wheat yields 64 pounds of semolina and 9 pounds of durum flour, which is used in pasta. Semolina is a fine granulation of the wheat kernel's endosperm and is the principal raw product used for pasta. The remaining product is used as a feed ingredient and fiber supplement in some foods. A commercial mill attempts to increase semolina production using less flour.

Durum wheat milled for pasta has to meet stringent quality factors. Mills in the United States require grade No. 2 Hard Amber Durum (HAD) or better. However, some No. 1 and No. 2 HAD may be rejected due to sprouted, bleached, or shrunken kernels. Durum that does not meet milling quality is exported or fed to livestock.

Model Development

The model used for this study is a static spatial programming model based on a mathematical programming algorithm. The model includes durum and semolina. The objective of the model is to minimize production costs of durum wheat at producing regions, distribution costs of durum from producing regions to mills and ports for export, and distribution costs of semolina from mills to final domestic and foreign consuming regions.

Quality of durum wheat is an important factor in trading durum in domestic and export markets. The quality of durum produced differs in each producing region and varies over time irregularly, mainly due to weather conditions and the growing season. Most mills in the United States accept only top quality durum. This implies U.S. exports of durum contain second best durum because the best quality goes to domestic mills. This quality restriction is incorporated into the model.

Quantities of durum produced in each region, quantities shipped to mills, quantities shipped for exports, quantities processed at mills, and quantities of semolina shipped for exports and domestic consumption are endogenous variables. The model includes seven durum exporting countries and eight importing countries. Exporting countries which account for over 90 percent of world durum exports are the United States, Canada, France, Greece, Spain-Portugal, Turkey, and Mexico. Importing countries which account for 83 percent of world durum imports are Italy, Algeria, Tunisia, USSR, Germany-Poland, Venezuela, Japan-Korea, and other European countries. The United States is divided into 28 producing regions (Figure 1) and 24 consuming regions (Figure 2). Canada is divided into five producing regions (Figure 1) and three consuming regions (Figure 2). All consuming regions have a consumption center which represents the location of the major pasta plant or plants in the region. Each consumption center (pasta plant) derives its demand for semolina upon the per capita pasta consumption and population for the particular consuming region. Thus, the pasta plant represents the point of consumption in this study. Other countries each have one producing region and one consuming region. Milling locations and capacities for the United States and Canada are shown in Figure 3. Some locations have more than one mill.

Mode of domestic transportation used for this study is rail. Barges are not used to ship durum mainly because durum producing regions in the United States and Canada are not located near the Mississippi or Columbia-Snake River systems. Consequently, shipping durum wheat to water access points by rail and then using a barge is not economically justified. Durum moved to ports is shipped to importing countries on ocean vessels. Semolina processed at mills is moved to consuming regions (pasta plants) by rail.

Assumptions used in developing the model are as follows:

1. Both domestic and import demand for durum and semolina are assumed to be perfectly inelastic in the model.

2. The model does not recognize storage activities at mills and ports, implying that all durum received must be used for domestic consumption and exports, respectively.

3. This study assumes durum wheat is moved from producing regions to mills and ports by rail.

4. Processing costs are assumed to be the same for each mill and are not included in this model.

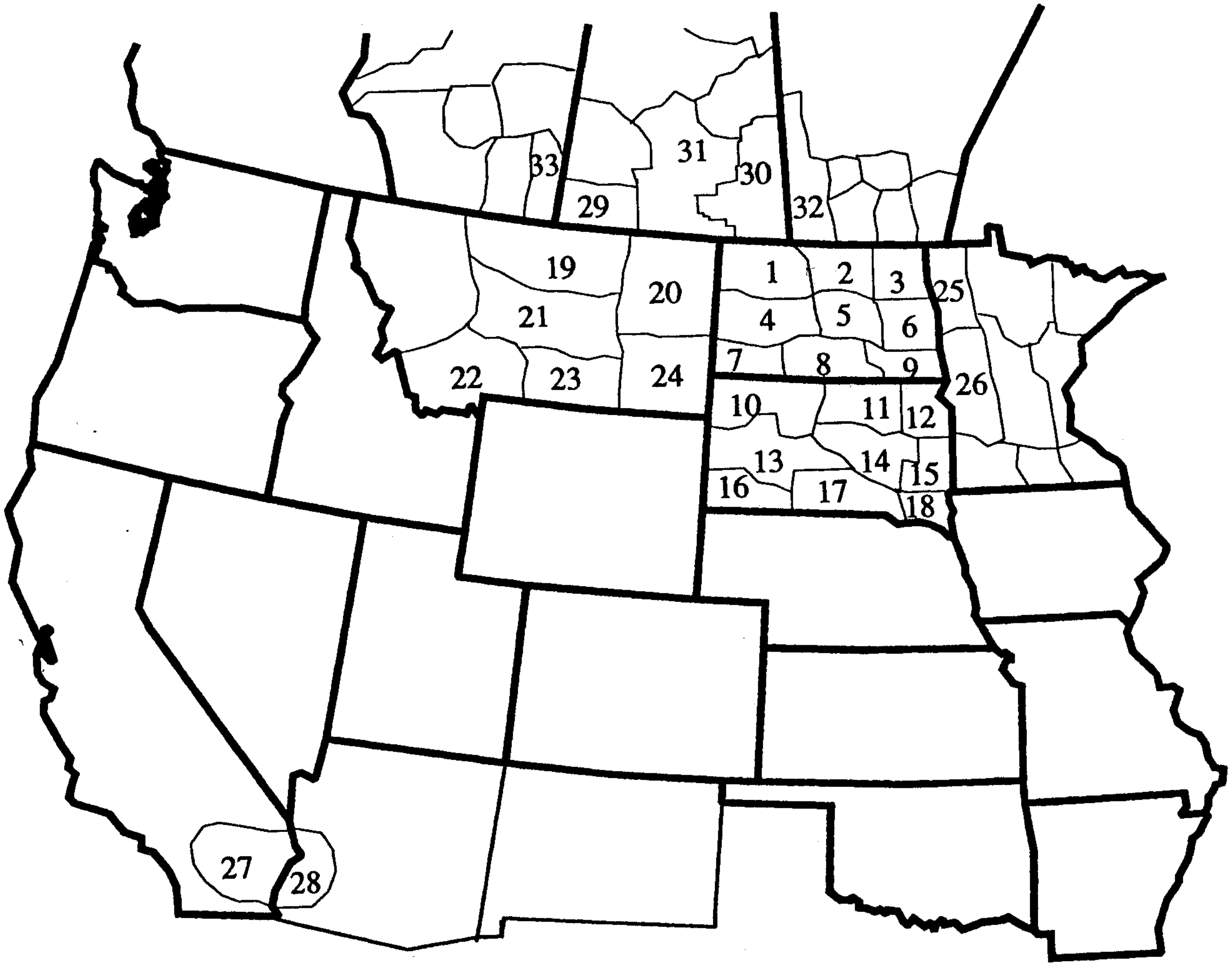

Figure 1. Durum Producing Regions in the United States and Canada

SOURCE: USDA, National Agricultural Statistics Service, 1991 and Statistics Canada, 1991.

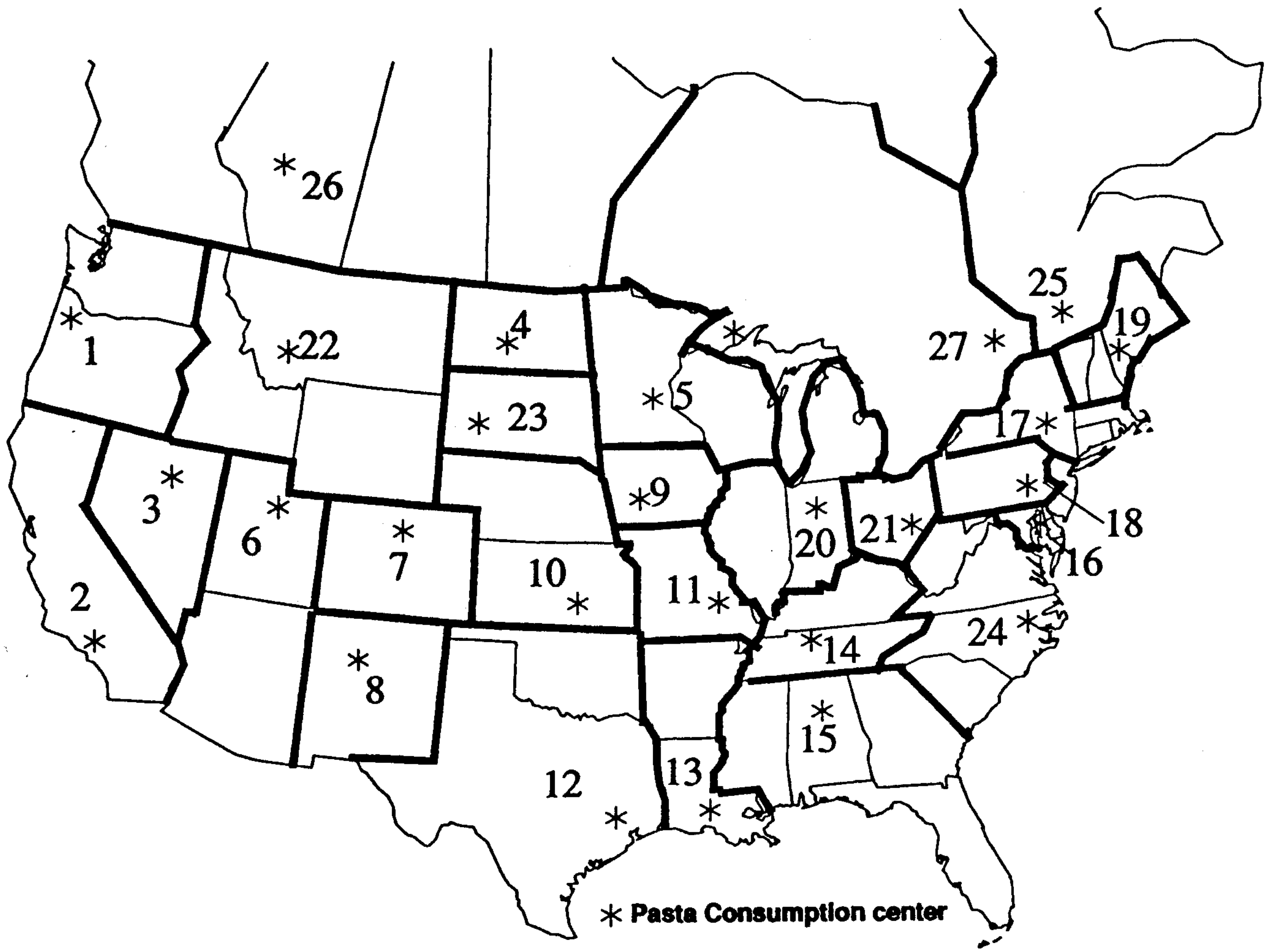

Figure 2. Pasta Consumption Regions in the United States and Canada

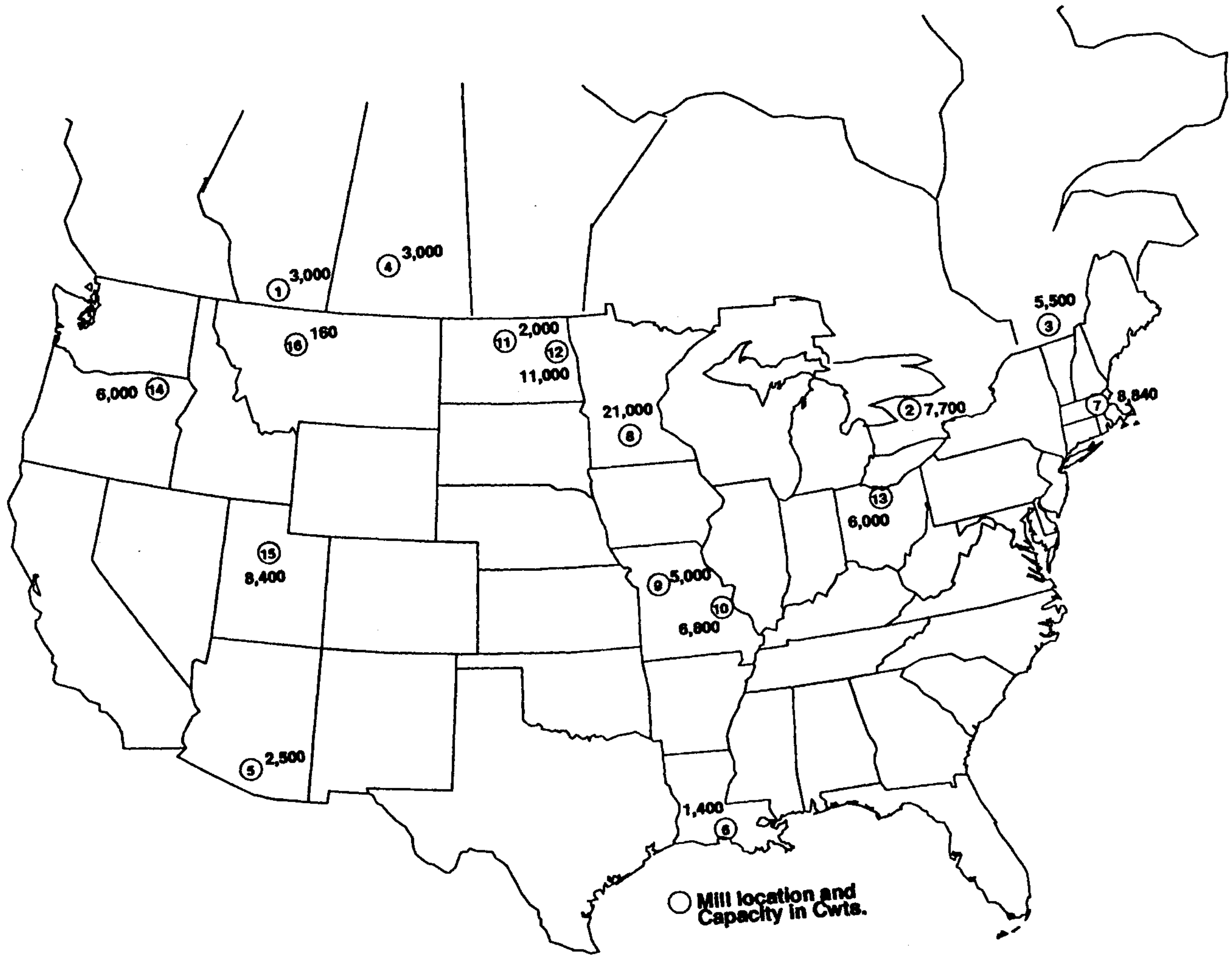

Figure 3. Durum Mills in the United States and Canada

SOURCE: <u>Milling and Baking News</u>, 1990.

The objective function of the model is written as follows:

$$\min C = \sum_{i=1}^{I} PC_i A_i + \sum_{i=1}^{I} \sum_{m=1}^{M} t_{im} Q_{im} + \sum_{i=1}^{I} \sum_{p=1}^{P} t_{ip} q_{ip} + \sum_{p=1}^{P} \sum_{n=1}^{N} t_{pn} Q_{pn} + \sum_{m=1}^{M} \sum_{c=1}^{C} t_{mc} QF_{mc} \qquad (1)$$

where

- i = index for producing region
- m = index for durum mills
- p = index for ports
- n = index for importing countries
- c = index for consuming regions
- PC = production cost per acre in producing region i
- A = number of acres used in producing region i
- t = transportation costs per metric ton in shipping durum from origins to destinations
- Q = quantity in metric tons of durum wheat transported from producing regions to domestic and foreign destination
- QF = quantity in metric tons of semolina transported from mills to destinations

The objective function in equation 1 is the summation of five separate activities. The first summation of equation 1 represents the total production cost in producing durum. The four remaining summations associated with shipments of durum are (1) shipments of durum wheat from producing regions to mills, (2) shipments of durum wheat from producing regions to ports, (3) shipments of durum wheat from ports to importing countries, and (4) shipments of semolina from mills to consuming regions. All costs of these activities are measured in dollars per metric ton.

Eight linear constraints are placed on the above model as follows:

$$UL_i \geq A_i \geq LL_i \qquad (2)$$

$$Y_i \bullet A_i \geq \sum_{i=1}^{I} x \sum_{m=1}^{M} Q_{im} + \sum_{i=1}^{I} \sum_{p=1}^{P} Q_{ip} \qquad (3)$$

$$D_c \leq \sum_{m=1}^{M} Q_{mc} \qquad (4)$$

$$MD_n \leq \sum_{p=1}^{P} Q_{pn} \qquad (5)$$

$$\delta \cdot \sum_{i=1}^{I} x Q_{im} = \sum_{c=1}^{C} QF_{mc} \tag{6}$$

$$\sum_{i=1}^{I} Q_{ip} = \sum_{n=1}^{N} Q_{pn} \tag{7}$$

$$C_m \geq \sum_{c=1}^{C} QF_{mc} \tag{8}$$

$$\lambda_i \cdot Y_i \cdot A_i \geq \sum_{m=1}^{M} Q_{im} \tag{9}$$

where

- UL_i = maximum acres of land that can be used for durum production
- LL_i = minimum acres of land that should be used for durum production
- Y_i = durum yield per acre in producing region i
- D_c = domestic consumption of durum flour in consuming region c
- MD_n = import demand for durum wheat in importing country n
- δ = technical coefficient converting durum to flour
- C_m = milling capacity
- λ_i = quality coefficient representing percent of durum which meets domestic milling standards in producing region i

Equation 2 represents land constraints for durum production. The total durum acres used for production should be less than the upper limit and more than the lower limit. Equation 3 refers to no excess demand equilibrium conditions, indicating that the total quantities of durum wheat produced in each region would be equal to or greater than the quantities shipped to domestic and foreign consuming regions.

Equation 4 represents demand for semolina in each consuming region. The total amount of semolina shipped from mills to a consuming region should be equal to or greater than the quantity demanded in the region. Equation 5 represents import demand for durum in each importing country. Interpretation of equation 5 is similar to equation 4. Equations 6 and 7 are inventory clearing conditions at mills and ports, respectively. Equation 7 forces durum wheat moved to ports to be exported, while equation 6 indicates that all durum shipped to mills should be processed and shipped out to consuming regions. The conversion factor, δ, used in this study is 0.7, which means that 0.7 pounds of semolina can be produced from 1 pound of durum.

Equation 8 represents milling capacity at each mill, indicating that each mill cannot process more than its daily capacity. Equation 9 shows constraints associated with durum wheat quality for domestic processing. This constraint is based on quality of durum in each producing region over the last 7 years. The equation represents domestic mills that accept top quality durum, which is λ percent of total production in each region. This implies that the remaining durum wheat produced $(1-\lambda)$ is available for exports.

Alternative Scenarios of Policy Simulation

The base model optimizes durum production and trade flows with existing trade policies of exporting and importing countries. Those included in the base model are U.S. and Canadian import tariffs, Canadian import license and rail rate subsidy for export shipments, the U.S. EEP, and the EC ERP. As stated previously, the trade policy variables included in this study are policies used by exporting countries. Trade restrictions used by importing countries are not included in this study because they are applied evenly to exporting countries, and thus, may not alter trade flows. Also, the primary focus of this study is on competition among exporting countries. Other policies such as Long-Term Agreements (LTA) and credit sales are not included because these policies are not consistently used, and consequently, it is difficult to quantify the parameters associated with these export policies. The base model solutions are compared with optimal solutions obtained from alternative models related to trade policies to analyze durum wheat production and trade flows under alternative policies.

The base and alternative models are as follows:

1. Model 1 (base model) is based on average data of 1986, 1987, and 1989 for production costs, yields and planted acres 1990 milling capacities, and demand for semolina and 1989 rail and ocean freight rates. In addition, Model 1 includes the existing trade policies of exporting and importing countries.
2. Model 2 is the same as Model 1 except for the exclusion of U.S. and Canadian tariffs and the Canadian import license for trading durum and semolina between the United States and Canada.
3. Model 3 is the same as Model 2 except for the additional exclusion of the Canadian rail rate subsidy.
4. Model 4 is the same as Model 1 without the U.S. EEP.
5. Model 5 is the same as Model 1 without the EC ERP.
6. Model 6 is the same as Model 1 without trade restrictions or subsidies discussed above.

Data

The model requires costs associated with production activities (production costs), domestic transportation activities (rail rates) and export activities (ocean freight rates), average yields in producing regions, and parameters in the constraints (arable land, domestic demand and foreign import demand).

Production Costs and Yields

Production costs for durum wheat in various countries are reported as average total variable costs to produce one acre of durum. Variable costs include all factors for producing durum except values on farmland and buildings. Since farm subsidy programs and economic conditions distort the values of land in a country, the land value does not represent productivity of land and differs from one country to another, depending upon each country's policies. This is the reason for excluding the value of farmland and buildings.

Production cost data for the United States were taken from an ERS publication entitled "State Level - 1985 Cost of Production" (McElroy 1987). Average production cost in each region was a weighted average of the state production costs based on total state acres planted in the region.

Production costs for Canadian durum wheat were based upon production costs received from the "Production Economics Branch" in each province. The production costs in 1990 Canadian dollars were converted to U.S. dollars, using the average 1990 exchange rate (IMF 1990).

Production costs in France, Greece, Spain-Portugal, and Turkey were obtained from both Stanton (1986) and FAS (April 1991). The production costs were converted to U.S. dollars, using the average 1986 and 1990 exchange rates (IMF 1987, 1990). Production costs for Mexico were obtained from FAS (April 1990).

U.S. production yields were obtained from USDA, National Agricultural Statistics Service (1990). A three-year average for 1986, 1987, and 1989 was used. Yields for 1988 were not used because of the drought that year. Average yields per acre for Canadian producing regions were taken from Agriculture Canada, Handbook of Selected Agricultural Statistics (1990). Average yields per acre for France, Greece, Spain-Portugal, and Turkey are obtained from FAS (April 1991). Average yields in Mexico were obtained from FAS. Average acres planted, average yield, and production costs per acre are presented in Table 4.

TABLE 4. AVERAGE ACRES HARVESTED, YIELD, AND PRODUCTION COSTS FOR DURUM BY PRODUCING REGION

Producing Region	Land	Yield	Production Costs
	(acres)	(bu/acre)	($/acre)
North Dakota			
ND-1	829,267	27.10	74.47
ND-2	567,000	29.80	74.47
ND-3	664,000	33.30	74.47
ND-4	232,833	28.20	74.47
ND-5	156,867	29.50	74.47
ND-6	53,200	37.40	74.47
ND-7	96,333	28.70	74.47
ND-8	24,667	24.60	74.47
ND-9	99,733	29.40	74.47
South Dakota			
SD-10	9,900	22.60	73.06
SD-11	30,900	27.80	73.06
SD-12	41,533	32.00	73.06
SD-13	367	22.70	73.06
SD-14	6,833	28.50	73.06
SD-15	367	31.10	73.06
SD-16	100	22.60	73.06
SD-17	400	23.80	73.06
SD-18	100	29.10	73.06
Montana			
MT-19	38,667	28.20	80.29
MT-20	208,667	21.50	80.29
MT-21	2,367	29.90	80.29
MT-22	400	53.00	80.29
MT-23	600	34.10	80.29
MT-24	867	25.60	80.29
Minnesota			
MN-25	24,065	39.00	98.50
MN-26	8,935	39.00	98.50
California			
CA-27	74,804	86.67	183.74
Arizona			
AZ-28	59,868	87.33	195.22
Saskatchewan			
SK-29	437,600	25.37	66.88
SK-30	996,000	24.27	66.88
SK-31	3,782,400	26.40	66.88
Manitoba			
MB-32	179,200	28.60	85.51
Alberta			
AB-33	399,000	29.70	72.38
France-34	1,000,000	55.00	214.50
Greece-35	1,300,000	35.00	168.00
Spain/Portugal-36	740,000	34.00	154.02
Turkey-37	320,000	25.00	112.50
Mexico-38	250,000	74.00	400.00

Marketing Costs

Transportation costs were divided into two parts: inland transportation by rail and ocean transportation. A rail rate function for transportation costs from producing regions to durum mills was estimated from selected sample routes. The estimated equation follows:

$$R_{ij} = (0.0143) * D_{ij}^{0.67743} \tag{10}$$

where

R_{ij} = rail rates for durum shipments between origin i and destination j,

D_{ij} = distances between origin i and destination j

This rail rate function was used to calculate rail rates from producing regions to durum mills by inserting the rail mileage between origin and destination. Rail mileages were calculated using the Railroad Atlas of the United States (Rand McNally Co. 1984).

Rail rates from durum mills to consuming regions were calculated in the same manner. The rail rate function estimated from selected sample routes follows:

$$FR_{im} = (.069) * D_{im}^{0.487959} \tag{11}$$

where

FR_{im} = freight rates for durum flour between origin i and destination m

D_{im} = distances between origin i and destination m

Ocean freight rates from exporting countries to importing countries were calculated by inserting the appropriate ocean mileage into the ocean freight function. Ocean mileages were calculated using The Times Atlas of Oceans (Time Books Limited 1983). Ocean freight rate function was estimated from the selected sample routes as follows:

$$OR_{pn} = 14.67 + 0.00156\ (OD_{pn}) \tag{12}$$

where

OR_{pn} = ocean freight for durum between origin p and destination n

OD_{pn} = ocean mileage between origin p and destination n

Tariffs

Tariffs between the United States and Canada apply to trade in both durum and semolina. U.S. tariffs on Canadian durum and semolina are higher than those Canada places on U.S. durum and semolina (Table 5).

TABLE 5. UNITED STATES AND CANADIAN TARIFFS PLACED ON BOTH DURUM AND SEMOLINA TRADE BETWEEN THE TWO COUNTRIES, 1991

Importing Country	Durum ($/mt)	Semolina ($/mt)
U.S.	5.00	7.00
Canada	2.69	3.42

SOURCE: International Trade Commission, 1991.

Constraints

Total available land for durum in each producing region is defined as being 50 Percent larger than average harvested acres for durum for 1986, 1987, and 1989. Lower limits of arable land, which are 50 percent of the actual harvested acres, are also introduced in the study. All data are taken from the USDA National Agricultural Statistics Service (1991) and Agriculture Canada (1990).

Total demand for semolina in each consuming region in the United States and Canada is calculated by multiplying per capita consumption of pasta in each region by the region's population (Table 6). Per capita consumption of pasta by consuming region was obtained from the National Pasta Association (1990). Demand for durum in other countries was obtained from FAS (1991) and converted to semolina consumption. Import demand for durum wheat in importing countries is a five-year average (1985-89) from FAS (1991) (Table 7). Milling capacity and location of durum mills in both the United States and Canada were taken from Milling and Baking News (1990) (Table 8). Each European country was assumed to have one mill with unlimited capacity due to data constraints.

Results

Results of this study are presented in five parts. First, a discussion of durum production by region is presented and analyzed for Model 1 (base model) and alternative models. Second, distribution of durum in both the U.S. and Canada, and world markets are presented and discussed for Model 1 and alternative models. Third, semolina flows are presented and discussed for Model 1. Fourth, regional and international production competitiveness is compared for the base and alternative models. Fifth, milling competitiveness is presented and compared for Models 1 and 2.

TABLE 6. PER CAPITA AND TOTAL CONSUMPTION OF PASTA BY PASTA CONSUMING REGIONS, 1990

Number of Consumption Region	Consumption Center	Consumption	
		Per Capita	Total
		(lbs.)	(1,000 lbs.)
1	Portland, OR	18.81	142,598.61
2	Los Angeles, CA	18.81	546,675.03
3	Winnemucca, NV	18.81	20,897.91
4	Bismarck, ND	18.81	12,414.60
5	St. Paul, MN	18.81	173,428.20
6	Salt Lake City, UT	15.39	26,270.73
7	Denver, CO	15.39	51,048.63
8	Albuquerque, NM	15.39	23,515.92
9	Des Moines, IA	15.39	43,707.60
10	Wichita, KS	15.39	63,468.36
11	St. Louis, MO	15.39	79,397.01
12	Houston, TX	15.39	311,108.85
13	Shreveport, LA	15.39	104,467.32
14	Nashville, TN	15.39	133,385.13
15	Birmingham, AL	15.39	451,819.62
16	Baltimore, MD	20.52	281,267.64
17	Syracuse, NY	20.52	368,334.00
18	Harrisburg, PA	20.52	247,060.80
19	Portland, ME	20.52	59,425.92
20	Indianapolis, IN	18.98	498,916.44
21	Columbus, OH	20.52	223,811.64
22	Butte, MT	15.39	35,320.05
23	Rapid City, SD	15.39	11,003.85
24	Raleigh, NC	15.39	277,604.82
25	Montreal, PQ	12.00	104,052.00
26	Edmonton, AB	12.00	83,712.00
27	Toronto, ON	12.00	103,500.00
28	France	19.97	1,122,000.00
29	Greece	31.43	314,600.00
30	Spain/Portugal	26.59	1,317,800.00
31	Turkey	63.89	3,625,600.00
32	Mexico	3.92	330,000.00

SOURCE: National Pasta Association, 1990 and FAS, 1991.

TABLE 7. DURUM IMPORTS BY MAJOR IMPORTING COUNTRIES OF DURUM, 1986, 1987, AND 1989

Importing Country	Imports
	----MT----
Italy	840,000
Algeria	1,420,000
Tunisia	240,000
USSR	800,000
East Germany/Poland	190,000
Venezuela	230,000
Japan/Korea	130,000
Other Europe[1]	180,000

[1]Includes Belgium, Netherlands, West Germany, and Switzerland

SOURCE: Foreign Agricultural Service, 1991.

TABLE 8. LOCATION AND DAILY CAPACITY OF DURUM MILLS IN THE UNITED STATES AND CANADA

Mill Location	Daily Capacity
	(CWT)
Lethbridge, AB	3,000
West Toronto, ON	7,700
Montreal, PQ	5,500
Saskatoon, SK	3,000
Tolleson, AZ	2,500
Port Allen, LA	1,400
Ayer, MA	8,840
Minneapolis, MN	21,000
Excelsior, MO	5,000
St. Louis, MO	6,800
Cando, ND	2,000
Grand Forks, ND	11,000
Huron, OH	6,000
Pendleton, OR	6,000
Ogden, UT	8,400
Big Sandy, MT	160

SOURCE: Milling and Baking News, 1990.

Model 1 is the base model with existing trade policies in all exporting countries. Model 2 addresses the impact of the U.S.-Canadian FTA (tariff and import license removal) and Model 3 eliminated the WGTA rail subsidy in Canada. The impacts of eliminating the U.S. EEP and the EC's ERP are presented in Models 4 and 5, respectively. Model 6 simulates worldwide free trade of durum.

Optimal Durum Production

Model 1 simulates competition among exporting countries based on production, rail transportation, and ocean freight costs and also includes the U.S. EEP, the EC (France, Greece and Spain-Portugal) ERP, and the Canadian WGTA rail subsidy. The optimal quantities of durum production for the United States, Canada, France, Greece, Spain-Portugal, Turkey, and Mexico are presented in Table 9. Total durum production in the major exporting countries is 3.15 mmt in the United States (larger than actual production), 1.65 mmt in Canada (less than half of actual production), 1.55 mmt in France (slightly more than actual), and .25 mmt in Greece (substantially less than actual production) (Table 4).

TABLE 9. ACTUAL DURUM PRODUCTION IN 1989 AND OPTIMAL DURUM PRODUCTION OF ALTERNATIVE MODELS

REGION	ACTUAL	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
	mmt						
North Dakota	1.82	2.40	2.53	2.58	1.67	2.40	3.11
South Dakota	0.08	0.08	0.08	0.12	0.07	0.08	0.12
Montana	0.18	0.05	0.05	0.05	0.05	0.05	0.05
Minnesota	0.03	0.06	0.06	0.06	0.01	0.06	0.06
Calif.-Ariz.	0.24	0.56	0.56	0.56	0.56	0.56	0.56
U.S. Total	**2.56**	**3.15**	**3.28**	**3.37**	**2.36**	**3.15**	**3.90**
Saskatchewan	3.06	1.10	1.10	1.10	1.84	1.85	1.10
Manitoba	0.24	0.07	0.04	0.04	0.04	0.04	0.04
Alberta	0.82	0.48	0.57	0.30	0.57	0.56	0.57
Canada Total	**4.12**	**1.65**	**1.71**	**1.45**	**2.44**	**2.45**	**1.71**
France	1.50	1.55	1.53	1.60	1.60	0.80	0.80
Greece	**1.23**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
Spain-Portugal	**0.68**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**
Turkey	**2.15**	**2.20**	**2.20**	**2.20**	**2.20**	**2.20**	**2.20**
Mexico	**0.50**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**

NOTE: Totals may not add due to rounding.

The impact of the U.S.-Canadian FTA on durum production and exports is simulated in Model 2. When tariffs and the Canadian import license are removed, both U.S. and Canadian durum production increase. The increase in U.S. durum production occurs in North Dakota; in Canada, durum production increases in Alberta, more than enough to offset a slight decrease in Manitoba. Production in Greece remains the same while France's production slightly decreases. The other producing countries have little change in production (Table 9).

Removing the Canadian rail subsidy (WGTA; Model 3), decreases durum production in Alberta because its location lends itself to exporting durum, putting Alberta in a less competitive position without the WGTA. Both North and South Dakota increase durum production, increasing U.S. production. France also increases production while Greece had no change.

Model 4 simulates the impact of eliminating the EEP. France's ERP and Canada's rail subsidy gave them a competitive advantage over the United States without EEP. Eliminating this program reduces durum production in the United States, particularly in North Dakota where production declines 30 percent. Minnesota also decreases production, primarily because it is near the port at Duluth. Both North Dakota and Minnesota have a large decrease in production for export (Appendix Table 4). Both Saskatchewan and Alberta increase durum production, Saskatchewan by 40 percent. France has a small increase in durum production.

The ERP of the EC (France and Greece) is removed in Model 5 and decreased French production. A small increase in U.S. production occurs in North Dakota while Canada has a large increase in durum production, mostly in Saskatchewan (Table 9).

Worldwide free trade of durum is simulated in Model 6 without subsidies and tariffs. The United States gains the most from worldwide free trade. Production in the United States increases to 3.90 mmt from 3.15 mmt in Model 1 (Table 9). North Dakota accounts for all of this increase with two-thirds of it going for export. Canadian production increases from 1.65 mmt in Model 1 to 1.71 mmt in Model 6, with all of the increase being in Alberta. Production in France declines 50 percent under free trade due to relatively higher production costs.

Distribution of Durum: Domestic and World Markets

The movement of durum for Model 1 from producing regions to durum mills is shown in Figure 4. Durum produced in North Dakota is shipped to mills in Minnesota, Missouri, Ohio, Louisiana, Massachusetts, and Utah and to local mills within North Dakota. Durum produced in South Dakota is shipped to mills in Minnesota, Utah, and Missouri. A small amount of durum grown in Minnesota

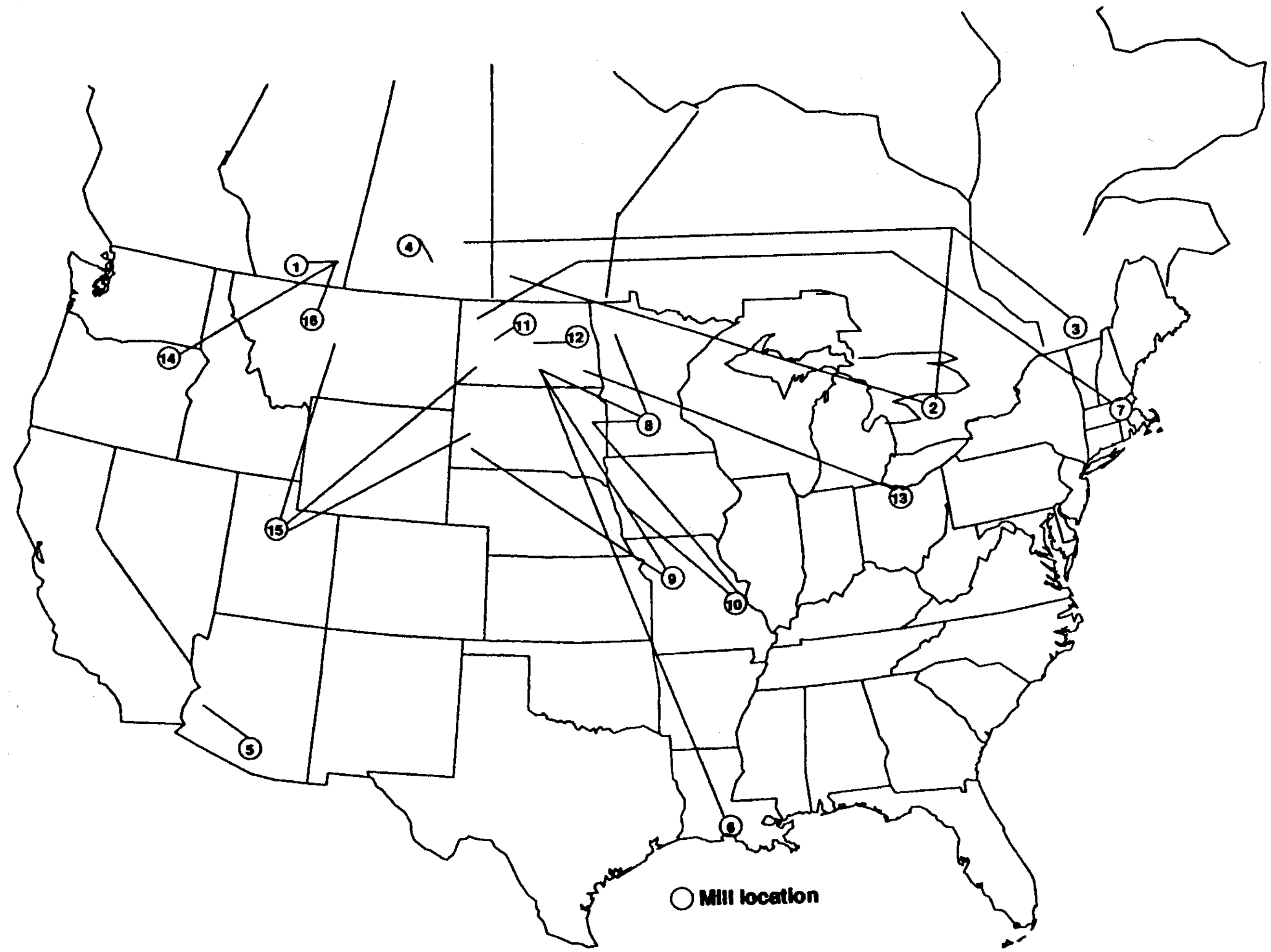

Figure 4. Optimal Distribution of Durum from Producing Regions to Mills in the United States and Canada, Model 1

and Montana is shipped to mills in Minnesota and Utah, respectively. Durum flows for the alternative models are similar to Model 1 and are not presented.

Durum produced in Alberta is shipped to the mill at Lethbridge, Alberta, and also exported to mills in Montana and Oregon. The mill in Montreal is supplied with durum from Saskatchewan, which also supplies durum to the mills in Saskatoon, Saskatchewan, and Toronto, Ontario. Durum produced in Manitoba is also shipped to Toronto, Ontario.

The United States and Canada export 1.66 and 1.53 mmt of durum, respectively, for Model 1 (Table 10). The major market for U.S. durum is Algeria, and Italy is the major market for Canadian durum. The USSR is the major export market for France and Greece, whose exports amount to .87 and .06 mmt, respectively. The United States and Canada have little bilateral trade. The Canadian import license effectively eliminates U.S. exports to Canada. Canadian exports to the United States amount to .09 mmt (Table 10).

TABLE 10. QUANTITIES OF DURUM EXPORTED TO MAJOR IMPORTING COUNTRIES FROM MAJOR EXPORTERS FOR MODEL 1

	United States	Canada	France	Greece
	MT			
Italy		840,000		
Algeria	1,420,000			
Tunisia	240,000			
USSR		48,839	694,160	57,000
E.G.-Poland		190,000		
Venezuela		230,000		
Japan-Korea	2,226	127,770		
Other Europe			180,000	
Canada				
United States		88,960[a]		
TOTALS	1,662,226 (40)	1,525,569 (37)	874,160 (21)	57,000 (2)

[a]Semolina in durum equivalent.

NOTE: Market shares are shown in parentheses.

The majority of U.S. durum is exported through the port at Duluth, which is the shortest access to major import markets in Northern Africa and Europe. All the producing regions in North and South Dakota and Minnesota ship durum to Duluth for Model 1 (Figure 5). The southern producing regions in Montana also ship durum to Duluth (Figure 5). All the durum exported from Duluth is shipped to Algeria, the major U.S. market, and Tunisia. Additional durum originating from California and Arizona is shipped to Algeria through the port at Long Beach. A small amount of durum originating from north central Montana is shipped through the port at Seattle to Japan-Korea.

The majority of Canadian exports originate from Thunder Bay, Ontario. Producing regions in Saskatchewan and Manitoba ship durum to the port at Thunder Bay for shipment to Italy, the largest Canadian market, and also to East Germany-Poland. The majority of durum produced in Alberta is exported through the port at Vancouver. Durum shipped through Vancouver is exported to the USSR, Venezuela, and Japan-Korea.

For Model 2, both U.S. and Canadian exports increase, primarily due to increased bilateral trade. Canada's exports to the United States increase from .09 mmt to .24 mmt and U.S. exports to Canada increase from zero in Model 1 to .11 mmt under the FTA. The major markets for both countries are the same as Model 1. France's exports decreased while Greece's exports remained the same (Table 11).

Canada is at a competitive disadvantage in producing durum for export without the WGTA rail subsidy. Canadian exports declined to 1.33 mmt in Model 3 with .70 mmt going to the United States. The primary reason for increased Canadian exports to the United States is the minimum land constraint used in the model. This constraint forces Canada to produce more than it can consume domestically, thereby leaving a large amount available for export. Since Canada cannot compete with the United States and the EC in exporting to traditional import markets, the model forces Canada to export its excess durum to the United States. Model 3 was run without the minimum land constraint and the results are presented in Table 12. Canadian exports to the United States declined to .38 mmt without the minimum land constraint, while U.S. exports to Canada increase from zero to .04 mmt. Total Canadian exports are .68 mmt, which is much smaller than with the minimum land constraint. Total U.S. exports are more without the minimum land constraint. The increase in U.S. exports fulfilled Italy's import demand, the major export market for Canada in both Models 1 and 2. France increased exports by exporting more durum to the USSR, also displacing Canadian durum. Greece's export volume does not change (Table 12).

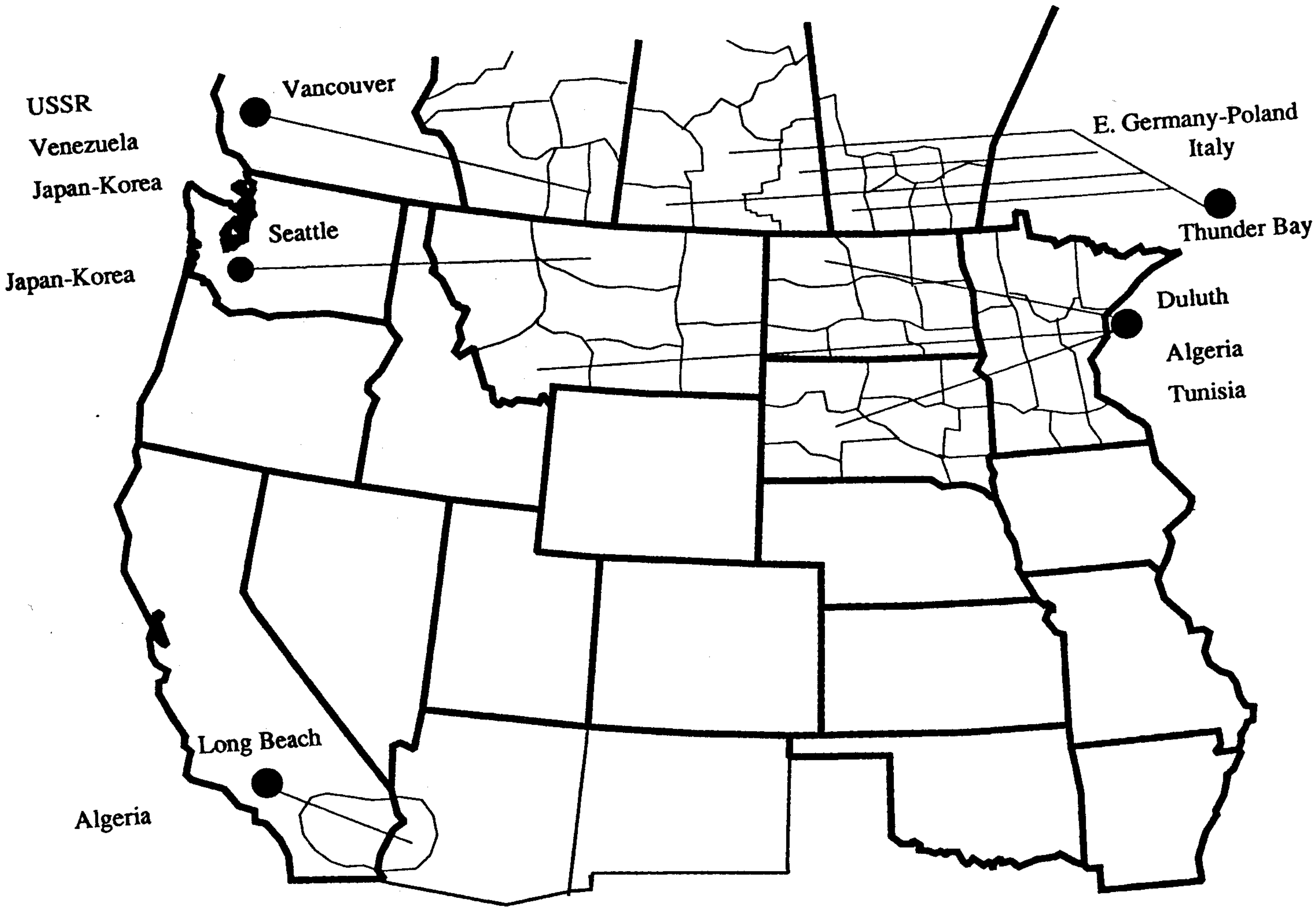

Figure 5. Optimal Distribution of Durum from Producing Regions to Export Ports and Importing Countries, Model 1

TABLE 11. QUANTITIES OF DURUM EXPORTED TO MAJOR IMPORTING COUNTRIES FROM MAJOR EXPORTERS FOR MODEL 2

	United States	Canada	France	Greece
	MT			
Italy		840,000		
Algeria	1,420,000			
Tunisia	240,000			
USSR		71,979	671,020	57,000
E.G.-Poland		190,000		
Venezuela		230,000		
Japan-Korea	2,226	127,770		
Other Europe			180,000	
Canada	107,128			
United States		236,116[a]		
TOTALS	1,769,354	1,695,865	851,020	57,000
	(41)	(39)	(19)	(1)

[a]Includes semolina in durum equivalent (118,869 MT)

NOTE: Market shares are shown in parentheses.

Elimination of the EEP is simulated in Model 4. U.S. exports decreased 50 percent from 1.66 to .82 mmt. North Dakota production for export decreased the most from Model 1 (Appendix Tables 1 and 4). Algeria is still the largest market for U.S. durum; however, only a third of Algeria's imports come from the United States. Canadian exports amount to 2.32 mmt, including .98 mmt to Algeria, the largest Canadian export market, and .82 mmt to Italy. Saskatchewan and Alberta both increase production for export, with exports from Saskatchewan nearly doubling. France increases its exports to .92 mmt with the majority going to the USSR. Greece exports .06 mmt to the USSR, the same level as in Model 1 (Table 13).

The elimination of the ERP (Model 5) allows Canada to displace French and Greek exports to the USSR, accounting for the entire increase in Canadian exports relative to Model 1. The United States has no change in exports, which indicates Canada has a competitive advantage over the United States in exporting to the USSR, probably due to the WGTA rail subsidy. France and Greece export to other Europe (Table 14).

TABLE 12. QUANTITIES OF DURUM EXPORTED TO MAJOR IMPORTING COUNTRIES FROM MAJOR EXPORTERS FOR MODEL 3

	United States	Canada	France	Greece
	---------MT---------			
Including minimum land constraint:				
Italy	840,000	--	--	--
Algeria	1,420,000	--	--	--
Tunisia	240,000	--	--	--
USSR	--	--	743,000	57,000
E.G.-Poland	112,040	77,957		
Venezuela	230,000	--	--	--
Japan-Korea	9,234	120,770	--	--
Other Europe	180,000	--		
Canada	--	--	--	--
United States	--	700,985[b]	--	--
Transhipments	(427,718)[a]	427,718	--	--
TOTALS	2,423,556 (51)	1,327,430 (28)	923,000 (22)	57,000 (2)
Excluding minimum land constraint:				
Italy	840,000	--	--	--
Algeria	1,420,000	--	--	--
Tunisia	240,000	--	--	--
USSR	--	--	800,000	--
EG-Poland	190,000	--	--	--
Venezuela	85,993	144,010	--	--
Japan-Korea	307	129,690	--	--
Other Europe	--	--	180,000	--
Canada	42,882	--	--	--
United States	--	375,277[c]	--	--
Transhipments	(26,376)[a]	26,376	--	--
Total	2,723,548 (62)	675,353 (15)	980,000 (23)	-- --

[a] Shipments of Canadian durum through the Duluth port.
[b] Includes semolina in durum equivalent (173,830 MT).
[c] Includes semolina in durum equivalent (161,018 MT).

NOTE: Market shares are shown in parentheses.

TABLE 13. QUANTITIES OF DURUM EXPORTED TO MAJOR IMPORTING COUNTRIES FROM MAJOR EXPORTERS FOR MODEL 4

	United States	Canada	France	Greece
	MT			
Italy	23,050	816,950		
Algeria	444,040	975,960		
Tunisia		240,000		
USSR			743,000	57,000
E.G.-Poland		190,000		
Venezuela	230,000			
Japan-Korea	130,003			
Other Europe			180,000	
Canada				
United States		97,982[a]		
TOTALS	827,093 (20)	2,320,892 (56)	923,000 (22)	57,000 (2)

[a]Includes flour in durum equivalent (42,564 MT).

NOTE: Market shares are shown in parentheses.

TABLE 14. QUANTITIES OF DURUM EXPORTED TO MAJOR IMPORTING COUNTRIES FROM MAJOR EXPORTERS FOR MODEL 5

	United States	Canada	France	Greece
	MT			
Italy		840,000		
Algeria	1,420,000			
Tunisia	240,000			
USSR		800,000		
E.G.-Poland		190,000		
Venezuela		230,000		
Japan-Korea	2,623	127,380		
Other Europe			123,000	57,000
Canada				
United States		144,378[a]		
TOTALS	1,662,623 (40)	2,331,758 (56)	123,000 (3)	57,000 (1)

[a]Includes semolina in durum equivalent (88,963 MT).

NOTE: Market shares are shown in parentheses.

The major changes in volume of exports under worldwide free trade (Model 6) are in the United States and France. The U.S. exports increase from 1.66 mmt to 2.81 mmt while French exports decrease from .87 mmt to .12 mmt. Exports to the United States, the largest market for Canadian durum, are one-third of Canada's export volume, while the United States does not export any durum to Canada. Algeria and Italy are the two major markets for U.S. durum. France and Greece export exclusively to other Europe (Table 15).

The minimum land constraint again forces Canada to produce more than it can consume domestically and most Canadian exports go to the United States. The minimum land constraint was removed from Model 6. Canadian exports to the United States decline from .41 mmt to .28 mmt while U.S. exports to Canada are .11 mmt. Total Canadian exports decline from 1.59 mmt to .93 mmt while total U.S. exports increase from 2.81 mmt to 3.30 mmt (Table 15). This implies that under world free trade, Canada could not compete with the United States in exporting to north African and European markets.

Distribution of Semolina: Model 1

The distribution of semolina from mills to pasta consumption regions in the United States and Canada is presented only for Model 1 because alternative models show little or no change in semolina distribution.

Most of the U.S. milling capacity is located in the midwest near major producing areas or in the eastern United States near major population centers. Mills in North Dakota and Minnesota ship semolina south and/or east to pasta consumption centers in New York, Pennsylvania, Maryland, Iowa, and North Carolina. Mills in Missouri ship semolina to Kansas, Texas, Louisiana, Alabama, and Tennessee. Mills in Montana, Oregon, Utah, and Arizona lack capacity to satisfy pasta demands in the western United States, so mills in Alberta and Saskatchewan ship semolina to several pasta consumption centers in the western United States (Figure 6). Mills in Toronto and Montreal satisfy local consumption and do not ship any semolina to other pasta consumption centers. Distribution of semolina in models 2 through 6 are similar to those in Model 1 and are not presented.

Regional and International Production Competitiveness

Competitiveness was measured two ways for this study. The first method is a ratio of acreage planted to the upper limit of land in each region (Table 16). The upper limit of land for durum production in each region is 50 percent above the three-year average (1986, 1987, 1989) of actual acreage planted in each region. The result is a number between zero, which is the least competitive, and one, which is the most competitive.

TABLE 15. QUANTITIES OF DURUM EXPORTED TO MAJOR IMPORTING COUNTRIES FROM MAJOR EXPORTERS FOR MODEL 6

	United States	Canada	France	Greece
	---MT---			
Including minimum land constraint:				
Italy	840,000	--	--	--
Algeria	1,420,000	--	--	--
Tunisia	198,280	41,721	--	--
USSR	211,088	588,920	--	--
E.G.-Poland	190,000	--	--	--
Venezuela	230,000	--	--	--
Japan-Korea	130,000	--	--	--
Other Europe	--		123,000	57,000
Canada	--			
United States	--	552,890[b]		
Transhipments	(405,087)[a]	405,087		
Totals	2,814,281 (61)	1,588,618 (35)	123,000 (3)	57,000 (1)
Excluding minimum land constraint:				
Italy	840,000	--	--	--
Algeria	1,420,000	--	--	--
Tunisia	240,000	--	--	--
USSR	263,646	536,350	--	--
E.G.-Poland	190,000	--	--	--
Venezuela	230,000	--	--	--
Japan-Korea	130,000	--	--	--
Other Europe	--	--	--	--
Canada	107,128	--	--	--
United States	--	280,435[c]	--	--
Transhipments	(118,030)[a]	118,030	--	
Totals	3,302,744 (75)	934,815 (21)	180,000 (4)	-- --

[a]Shipments of Canadian durum through the Duluth port.
[b]Includes semolina in durum equivalent (114,416 MT).
[c]Includes semolina in durum equivalent (86,744 MT).

NOTE: Market shares are shown in parentheses.

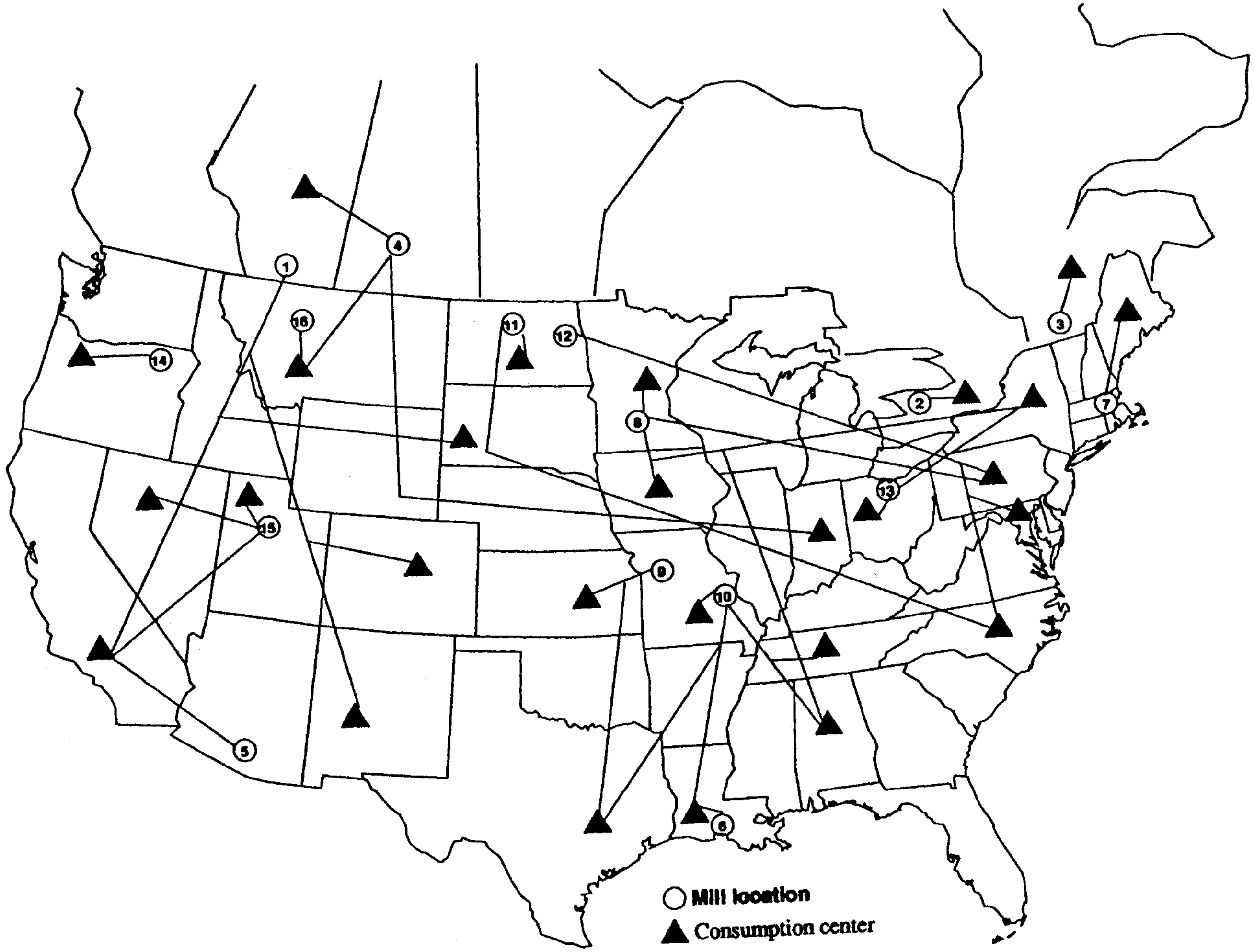

Figure 6. Optimal Distribution of Semolina from Mills to Consumption Centers in the United States and Canada, Model 1

TABLE 16. PERCENT OF LAND USED FOR MODEL 1 AND ALTERNATIVE MODELS

REGION	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
North Dakota	0.59	0.60	0.64	0.41	0.60	0.79
South Dakota	0.62	0.62	0.90	0.56	0.62	0.90
Montana	0.17	0.17	0.17	0.17	0.17	0.18
Minnesota	1.00	1.00	1.00	0.17	1.00	1.00
Calif.-Ariz.	1.00	1.00	1.00	1.00	1.00	1.00
United States	0.58	0.59	0.63	0.41	0.58	0.75
Saskatchewan	0.17	0.17	0.17	0.28	0.28	0.17
Manitoba	0.17	0.17	0.17	0.17	0.17	0.17
Alberta	1.00	1.00	0.53	1.00	1.00	1.00
Canada	0.23	0.23	0.20	0.33	0.33	0.23
France	0.49	0.49	0.51	0.51	0.26	0.26
Greece	0.10	0.10	0.10	0.10	0.10	0.10

The second method is a weighted shadow price calculated from shadow prices generated for the upper limit of the land constraint. The ratio of total acreage in each crop reporting district to the upper limit of acreage in each region is used as the weight. This weight was multiplied by the corresponding shadow price to compute a weighted shadow price (Table 17). These shadow prices indicate the amount the objective function would decrease if another acre of land is put into production. Thus, the higher the weighted shadow price, the more competitive the region is in producing durum.

Both measures of competitiveness indicate California-Arizona is the most competitive region in producing durum mainly because its near the export port at Long Beach. Also, it is the only major durum-producing area in the western United States, giving it a transportation advantage in meeting this area's pasta consumption. This area also has a large population base to support production of durum for pasta products. In terms of percent of land used, Minnesota is tied with California-Arizona as the most competitive region; in terms of weighted shadow price, South Dakota is more competitive than Minnesota.

South Dakota's low production costs, proximity to the port at Duluth, and its transportation advantage in shipping durum to two major mills in Missouri make it a competitive durum producer. Minnesota is a competitive durum producer because of the proximity of the port at Duluth and major mills located in Minneapolis and Grand Forks. Montana is the least competitive durum producer in the United States because of its distance to both ports and mills. Most of the durum produced in Montana is

TABLE 17. WEIGHTED SHADOW PRICES BY REGION FOR MODEL 1 AND ALTERNATIVE MODELS

REGION	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
North Dakota	5.64	5.64	10.32	5.04	5.63	11.09
South Dakota	9.18	9.18	10.12	6.67	9.18	13.41
Montana	0.64	0.64	0.67	0.57	0.68	0.90
Minnesota	3.78	3.78	11.02	0.00	3.78	15.36
Calif.-Ariz.	34.48	34.48	50.65	16.06	34.48	76.73
Saskatchewan	0.00	0.00	0.00	0.00	0.00	0.00
Manitoba	0.00	0.00	0.00	0.00	0.00	0.00
Alberta	0.74	0.74	0.00	1.63	4.74	6.93
France	0.00	0.00	0.00	0.00	0.00	0.00
Greece	0.00	0.00	0.00	0.00	0.00	0.00

either shipped to Utah for milling or competes with durum grown in the Dakotas and Minnesota for export through the port at Duluth.

Alberta is more competitive than Saskatchewan and Manitoba in producing durum (Tables 16 and 17). Alberta has lower production costs than Manitoba but higher costs than Saskatchewan. Alberta has a transportation advantage over Saskatchewan in shipping durum to the Vancouver port. This transportation advantage offsets Alberta's higher production cost and gives it a competitive advantage in exporting through Vancouver. Canada's major mills are located in Ontario and Quebec near population centers, which give Saskatchewan a competitive advantage in producing for domestic consumption. Manitoba is the least competitive province due to higher production costs relative to Alberta and Saskatchewan. Manitoba's transportation advantage to the port at Thunder Bay does not offset Saskatchewan's advantage in production costs.

France has a competitive advantage over Greece in producing durum in the EC due to lower production costs. Competitiveness for Spain-Portugal, Turkey, and Mexico are not calculated since they do not export durum in any models.

Countries are compared in terms of competitiveness using the percent of land used (Table 16). The United States is the most competitive country for Model 1 because of low production costs, and well-developed railroads. France has higher production costs than Canada but is more competitive because of its proximity to importing countries. Although Greece is also relatively close to importing countries, its production costs are too high for it to be a competitive exporter.

The alternative models have some changes in competitiveness. The U.S.-Canadian FTA (Model 2) has little or no effect on any region or country's competitive position. Only North Dakota had a small increase in competitiveness. Elimination of the WGTA rail subsidy (Model 3) increases the competitive position of all producing regions in the United States, except Montana, and in Canada decreases the competitive position of Alberta, while neither measure of competitiveness changes for Saskatchewan and Manitoba. France had a small increase in competitiveness and Greece had none for any alternative models.

Model 4 eliminates the EEP, which greatly reduces the competitiveness of the United States, particularly North Dakota and Minnesota. Canada's competitive position increases in Alberta and Saskatchewan. France has a small increase in competitiveness.

Model 5 eliminates the ERP for the EC (France and Greece), which reduces the competitiveness of France, while Greece remains unchanged. Comparing Model 1 with Model 5 indicates no change in competitiveness for the United States, but Canada's competitiveness increases. Model 6 eliminates all trade restrictions and subsidies resulting in world free trade. The United States gains the most from free trade while Canada's competitive position does not change and France experiences a large decrease in competitiveness. All producing regions in the United States increase their competitive position, except for Montana. Alberta is the only province in Canada to increase its competitiveness.

Milling Competitiveness

The United States has sixteen durum mills and Canada four. These mills compete on the basis of costs of durum sent to them and transportation costs from producing regions to mills and those from durum mills to pasta consumption regions. Milling costs are not included in the spatial equilibrium model, and thus, are not reflected in mill competitiveness. Shadow prices for each mill are used to measure mill competitiveness. The more negative the shadow price, the more competitive the mill. Relative changes in shadow prices between Models 1 and 2 are analyzed to determine the impact of the U.S.-Canada FTA (Table 18).

Model 1 indicates the most competitive mill in the United States is in Arizona, primarily because it is near the only durum-producing region in the western United States (Table 18). The mills in Massachusetts, Oregon and Utah are the least competitive. In general, the farther a mill is from a producing region, the less competitive the mill. Mills in North Dakota, Minnesota, and Missouri compete with mills in Alberta and Saskatchewan for the pasta market in the western United States.

The most competitive Canadian mill is in Alberta near the U.S.-Canadian border, making it competitive in shipping semolina to the western United States.

The U.S.-Canadian FTA increases competitiveness of Canadian mills in Alberta and Saskatchewan while all mills in the U.S. decline in competitiveness (Table 18). Canadian semolina exports to the United States increase from .09 mmt in Model 1 to .12 mmt in Model 2. Most of the increase is from the mill in West Toronto, which shipped semolina to New York in Model 2, displacing semolina shipped from Minneapolis to New York in Model 1. Mills in North Dakota, Arizona, and Montana are the only mills more competitive than the mill in Alberta.

There is little change in the order of mill competitiveness for Models 3 through 6. Mills in Arizona, North Dakota, and Minnesota remain the most competitive for these models. Mills in Oregon, Utah, and Massachusetts remain the least competitive.

Summary and Conclusions

A spatial equilibrium model was developed to evaluate optimal production and distribution of durum for milling and export based on competitive advantage in terms of production and marketing costs, given the following export subsidy programs: the U.S. EEP, the Canadian WGTA, the EC's ER program, and tariffs between the U.S. and Canada. Five additional models are simulated to analyze the impacts of the U.S.-Canadian FTA, elimination of each country's export subsidy, and worldwide free trade.

The base model (Model 1) indicates the United States produced and exported more durum than actual production and exports in 1989 under current export policies. North Dakota and California-Arizona are the major producing regions in the United States, while Saskatchewan and Alberta are the major producers in Canada. France and Greece are the only exporting countries for the EC.

The U.S.-Canadian FTA has little impact on world production and export flows of durum. Both U.S. and Canadian production increase while production in France marginally declines. Exports increase for both countries, primarily due to increased bilateral trade. Canadian producers may benefit more from the FTA than U.S. producers because of a larger percentage increase in production.

The United States, Canada, and EC cannot compete with each other in exporting durum without their respective subsidy programs. The U.S. and French durum exports decrease the most without their subsidy programs. However, Canada had only a small decrease in exports, mainly because exports to the United States are increased. Removing Canada's WGTA rail subsidy increases exports to the United States even though total exports fall; half of Canada's exports are to the United States.

TABLE 18. SHADOW PRICES FOR MODELS 1 THROUGH 6, CANADA AND THE U.S.

MILL LOCATION	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6
Canada						
Lethbridge, AB	-13.37	-16.21	-16.21	-7.69	-6.77	-13.26
West Toronto, ON	0.00	0.00	0.00	0.00	0.00	0.00
Montreal, PQ	0.00	0.00	0.00	0.00	0.00	0.00
Saskatoon, SK	0.00	-1.23	-4.99	0.00	0.00	-4.99
United States						
Tolleson, AZ	-43.56	-39.40	-31.52	-48.84	-43.56	-22.87
Port Allen, LA	-7.01	-2.27	0.00	-13.59	-10.60	0.00
Ayer, MA	0.00	0.00	0.00	0.00	0.00	0.00
Minneapolis, MN	-17.05	-7.77	-3.37	-22.44	-20.65	-3.96
Excelsior, MO	-14.19	-4.91	-5.50	-15.18	-17.79	-5.50
St. Louis, MO	-10.16	-0.88	-3.23	-12.03	-13.75	-3.23
Cando, ND	-27.98	-18.70	-14.30	-33.37	-31.57	-14.89
Grand Forks, ND	-31.65	-22.37	-17.97	-37.03	-35.24	-18.55
Huron, OH	-10.82	-1.54	0.00	-16.21	-14.41	-0.07
Pendelton, OR	0.00	0.00	0.00	0.00	0.00	0.00
Ogden, UT	0.00	0.00	0.00	0.00	0.00	0.00
Big Sandy, MT	-21.98	-17.82	-17.82	-18.42	-17.53	-17.53

World free trade of durum would benefit the United States, have little or no impact on Canada, and hurt France. Under free trade, France cannot compete with the United States because of higher production costs. This increases U.S. production, particularly in North Dakota where all the durum is exported. Canadian exports of durum to the United States increases, allowing Canada to maintain production and export levels similar to those in Models 1 and 2. The primary reason for increased Canadian exports to the United States is the minimum land constraint used in the model. This constraint forces Canada to produce more than it can consume domestically, thereby leaving a large amount available for export. Since Canada cannot compete with the United States and the EC in exporting to traditional import markets, the model forces Canada to export its excess durum to the United States, which must export more of its durum to northern Africa and Europe. The lower bound of land constraints was removed which reduced Canadian exports to the United States.

An important conclusion is that if all exporting countries eliminate their subsidies simultaneously, the United States would gain more than the other exporting countries. North Dakota would greatly benefit in terms of increased production under world free trade.

This study provides important information for producers, traders, and government policy makers. The study does contain some limitations which should be considered when interpreting its results. One limitation is that the linear programming model used in this study minimizes total production and marketing costs unlike quadratic models which maximize social welfare. Therefore, from this study we cannot infer whether producers (or consumers) are better or worse off from changes in production and export levels. The second limitation is the exclusion of processing costs due mainly to unavailability of data. Thus, optimal results cannot be interpreted in terms of absolute magnitude but rather in terms of order and changes in magnitude. A final limitation is that the model does not allow stock at ports or mills. This may cause durum to be exported which otherwise would be put in stock.

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APPENDIX

APPENDIX TABLE 1. TOTAL PRODUCTION AND EXPORTS OF DURUM FOR MODEL 1

REGION	ACREAGE	PRODUCTION		
		MILL	EXPORTS	TOTAL
North Dakota	2,829,350	1,293,835	1,103,437	2,397,272
South Dakota	97,958	65,810	16,453	82,263
Montana	76,920	36,207	12,069	48,276
Minnesota	57,750	33,525	27,772	61,297
Calif.-Ariz.	235,680	55,303	502,500	57,803
U.S. Total	3,297,658	1,484,680	1,662,231	3,146,911
Saskatchewan	1,564,800	119,349	983,969	1,103,318
Manitoba	53,600	25,033	46,033	71,066
Alberta	698,600	66,364	406,610	472,974
Canada Total	2,317,000	210,746	1,436,612	1,647,358
France	1,038,300	680,000	874,160	1,554,160
Greece	260,000	190,670	57,000	247,670
Spain-Portugal	863,100	798,670	0	798,670
Turkey	3,229,500	2,197,300	0	2,197,300
Mexico	99,305	200,000	0	200,000

APPENDIX TABLE 2. TOTAL PRODUCTION AND EXPORTS OF DURUM FOR MODEL 2

		PRODUCTION		
	ACREAGE	MILL	EXPORT	TOTAL
North Dakota	2,857,880	1,316,976	1,210,564	2,527,540
South Dakota	97,958	65,810	16,453	82,263
Montana	76,920	36,207	12,069	48,276
Minnesota	57,750	33,525	27,772	61,297
Calif.-Ariz.	235,680	55,303	502,500	557,803
U.S. Total	3,326,188	1,507,821	1,770,358	3,278,179
Saskatchewan	1,564,800	66,364	1,036,950	1,103,314
Manitoba	53,600	0	41,721	41,721
Alberta	698,600	66,364	498,327	564,691
Canada Total	2,317,000	132,728	1,576,998	1,709,726
France	1,022,800	680,000	851,020	1,531,020
Greece	260,000	190,670	57,000	247,670
Spain-Portugal	863,100	798,670	0	798,670
Turkey	3,229,500	2,197,300	0	2,197,300
Mexico	99,305	200,000	0	200,000

APPENDIX TABLE 3. TOTAL PRODUCTION AND EXPORTS OF DURUM FOR MODEL 3

		PRODUCTION		
	ACREAGE	MILL	EXPORT	TOTAL
North Dakota	3,051,330	719,323	1,857,983	2,577,306
South Dakota	142,763	92,930	23,232	116,162
Montana	76,920	36,207	12,069	48,276
Minnesota	57,750	33,525	27,772	61,297
Calif.-Ariz.	235,680	55,303	502,500	557,803
U.S. Total	3,360,844	937,288	2,423,556	3,360,844
Saskatchewan	1,564,800	226,989	876,322	1,103,311
Manitoba	53,600	0	41,721	41,721
Alberta	373,510	66,364	235,556	301,920
Canada Total	1,991,910	293,353	1,153,599	1,446,952
France	1,070,900	680,000	923,000	1,603,000
Greece	260,000	190,670	57,000	247,670
Spain-Portugal	863,100	798,670	0	798,670
Turkey	3,229,500	2,197,300	0	2,197,300
Mexico	99,305	200,000	0	200,000

APPENDIX TABLE 4. TOTAL PRODUCTION AND EXPORTS OF DURUM FOR MODEL 4

		PRODUCTION		
	ACREAGE	MILL	EXPORT	TOTAL
North Dakota	1,932,780	1,255,683	417,056	1,672,739
South Dakota	88,050	59,662	14,915	74,577
Montana	76,920	36,207	12,069	48,276
Minnesota	9,900	7,881	2,627	10,508
Calif.-Ariz.	235,680	177,372	380,432	557,804
U.S. Total	2,343,330	1,536,805	827,099	2,363,904
Saskatchewan	2,586,600	74,190	1,763,270	1,837,460
Manitoba	53,600	25,033	16,689	41,722
Alberta	698,600	66,364	498,369	564,693
Canada Total	3,338,800	165,587	2,278,328	2,443,915
France	1,070,900	680,000	923,000	1,603,000
Greece	260,000	190,670	57,000	247,670
Spain-Portugal	863,100	798,670	0	798,670
Turkey	3,229,500	2,197,300	0	2,197,300
Mexico	99,305	200,000	0	200,000

APPENDIX TABLE 5. TOTAL PRODUCTION AND EXPORTS OF DURUM FOR MODEL 5

	ACREAGE	PRODUCTION		
		MILL	EXPORT	TOTAL
North Dakota	2,838,410	1,288,349	1,116,277	2,404,626
South Dakota	97,958	65,810	16,453	82,263
Montana	76,920	36,207	12,069	48,276
Minnesota	57,750	45,973	15,324	61,297
Calif.-Ariz.	235,680	55,303	502,500	557,803
U.S. Total	3,306,718	1,491,643	1,662,623	3,154,265
Saskatchewan	2,600,000	119,349	1,727,779	1,847,128
Manitoba	53,600	25,033	16,688	41,721
Alberta	698,600	66,364	498,328	564,692
Canada Total	3,352,200	210,746	2,242,795	2,453,541
France	536,450	680,000	123,000	803,000
Greece	260,000	190,670	57,000	247,670
Spain-Portugal	863,100	798,670	0	798,670
Turkey	3,229,500	2,197,300	0	2,197,300
Mexico	99,305	200,000	0	200,000

APPENDIX TABLE 6. TOTAL PRODUCTION AND EXPORTS OF DURUM FOR MODEL 6

		PRODUCTION		
	ACREAGE	MILL	EXPORT	TOTAL
North Dakota	3,753,980	851,293	2,260,439	3,111,732
South Dakota	142,763	92,930	23,232	116,162
Montana	80,353	38,302	12,767	51,069
Minnesota	57,750	45,973	15,324	61,297
Calif.-Ariz.	235,680	55,303	502,500	557,803
U.S. Total	4,270,526	1,083,801	2,814,263	2,998,064
Saskatchewan	1,564,800	607,632	495,677	1,103,309
Manitoba	53,600	0	41,721	41,721
Alberta	698,600	66,364	498,328	564,694
Canada Total	2,317,000	673,996	1,035,728	1,709,724
France	536,450	680,000	123,000	803,000
Greece	260,000	190,670	57,000	247,670
Spain-Portugal	863,100	798,670	0	798,670
Turkey	3,229,500	2,197,300	0	2,197,300
Mexico	99,305	200,000	0	200,000