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USDA'S WORLD WHEAT TRADE MODEL

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This report begins by providing a brief description of the microcomputer-based World Wheat Model housed in the Economic and Trade Policy Branch, International Economics Division, Economic Research Service. This is followed by a validation of the base solution results. The model is then used to analyze the shortrun impact upon trade of a one-time 5-percent cut in U.S. production. The impact of a multiyear 5-percent cut in U.S. production is studied next. Finally, a limited trade liberalization scenario is examined.

Overview of Model

The Wheat Trade Model used for this analysis is a single-commodity, competitive, spatial price equilibrium model that assumes wheat to be a homogeneous product. It is a synthetic model that disaggregates the world wheat market into 23 regions, 6 of which are exporting regions and the remaining 17 importing regions. The time period modeled is the 1984/85 wheat marketing year (July-June).

Each country or region in the model is represented by an excess supply or excess demand function. Elasticity coefficients from other studies are used to generate the excess demand and supply schedules. The model is designed to reproduce the net trade of each region for the base period.

Trade flows are constrained to simulate actual bilateral agreements or export or import quotas. Tariffs, taxes, and subsidies are introduced through price linkage equations. A transportation cost matrix is specified that links exporter and importer prices.

The solution algorithm used for the World Wheat Model is the Generalized Transportation Program (GTP). GTP is a software package that solves single-commodity trade problems on microcomputers (1). 1/ GTP uses the vector sandwich method to find a solution.

The model is validated in that the simulated trade flows can be compared with actual trade flows for the base period. A well-designed version should accurately reproduce the net trade of each region, but trade flows between specific exporters and importers are difficult to replicate. There are always fewer flows in the model than in the real world.

The primary purpose of this model is to examine the shortrun impact on the world wheat market of alternative trade policies, changes in exchange rates, or changes in transportation costs. A recent use of a 1980-base model is in Holland and Sharples (2). That report also gives details on the assumptions made. Table 1 provides the elasticity coefficients used for building the equations for the 1984/85 shortrun wheat model. Actual 1984/85 bilateral wheat agreements among the various importers and exporters are presented in table 2, along with other constraints.

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1/ Underscored numbers in parentheses refer to sources cited in the References.

Base Solution

Actual 1984 trade flows are shown in table 3 and the model solution is shown in table 4. Three generalizations can be made concerning the base solution. First, the quantities traded by each region approximate actual regional net trade. The difference between actual net trade and the model's solution is less than 1 percent for all exporters and importers, except Brazil (1.4 percent). With patience, the model could be tuned so it perfectly reproduces actual net trade for every region.

Second, region-to-region trade flows in the solution do not match actual trade flows very well. During the base period, each of the major wheat exporters

Table 1--Net wheat imports (exports) and assumed elasticities, 1984/85

Region	Net imports/exports	Elasticity of excess demand/supply
	1,000 metric tons	
Importing:		
Mexico	488	-0.20
Brazil	5,400	-.20
Other Latin America	7,061	-.40
EC-10	2,283	0
Other Western Europe	1,690	0
Eastern Europe	2,602	0
Soviet Union	28,100	-.25
China	7,500	-.80
Japan	5,722	0
East Asia	4,315	-.40
Southeast Asia	1,465	-.80
South Asia	6,580	-.80
West Asia	11,882	0
North Africa	12,684	0
Central Africa	5,680	-.80
South Africa	470	0
Other	2,627	--
Total	106,559	--
Exporting:		
Canada	19,456	.50
United States	38,092	.75
Argentina	8,034	.10
EC-10	17,500	0
Australia	15,265	.25
Other	8,212	--
Total	106,559	--

-- = Not calculated.
Source of trade data: Foreign Agricultural Service, USDA.

shipped wheat to nearly all of the world's importing regions. The model results, on the other hand, suggest considerably more specialization--a feature of spatial equilibrium models. The model captures the major trade flows from the United States, Canada, Argentina, and Australia, but many of these flows--especially to the Soviet Union and China--are determined by minimum flow constraints. The greatest divergence between actual exports and the model's solutions is for the European Economic Community (EC-10). While the model results indicate that the EC-10 exports to only five regions, the EC-10 in reality exported to all regions, except Mexico and Japan. Among major importers, model and simulated trade flows are reasonably close for only China, Japan, and the Soviet Union. Great divergence exists for West Asia and North Africa, both of which imported wheat from all major exporters during the 1984/85 marketing year.

Third, by design, the model's estimate of the average border export price for the United States is the same as the actual. Price differentials among exporters in the solution are due to differentials in the transportation cost matrix. These differentials accurately reflect real world export price differentials between the United States and Argentina and between the United

Table 2--Trade flow constraints and total net trade constraints

Importers	Canada	United States	Argentina	EC-10	Australia	Other	Net trade
			1,000 metric tons				
Mexico	--	--	>25	--	--	2/ =34	--
Brazil	1/ >1,300	--	--	--	--	=434	--
Other Latin America	--	--	>600	--	--	=347	--
EC-10	--	--	--	--	--	--	=2,283
Other Western Europe	--	--	--	--	--	--	=1,690
Eastern Europe	>100	--	--	--	--	=1,114	=2,602
Soviet Union	>6,000	>6,000	>3,600	>5,700	>1,800	=1,934	--
China	>2,700	>2,400	>673	--	>1,500	--	--
Japan	>1,300	--	--	--	>900	--	=5,722
East, South, and Southeast Asia						=1,329	--
West Asia	>900	--	>300	--	>1,260	=1,572	=11,882
North Africa	>950	--	--	--	>1,500	=1,397	=12,684
Other Africa	>100	--	>40	--	--	=51	--
Other	--	=952	=140	=1,173	=362	--	=2,627
Net trade	--	--	--	=17,500	--	=8,212	--

-- = Not applicable.

1/ > Stands for greater than or equal to and represents a constraint imposed by a bilateral trade agreement.

2/ = is an equality constraint indicating no quantity response to changes in border prices.

Source: Foreign Agricultural Service, USDA.

States and Australia. The model's estimate of the border price for Canada, however, is underestimated. The divergence that exists for Canadian prices may be attributed largely to the higher quality of wheat exported by Canada. Conversely, the higher border price obtained in the model solution for the EC-10 may reflect the model's inability to account for the lower quality of wheat exported by the EC-10. Quality differences are not captured by the model.

Results of a 5-Percent Production Decline in the Short Run

U.S. wheat production in 1984/85 was 70.6 million metric tons (MMT). A 5-percent (3.5 MMT) production shortfall was introduced into the modeling framework by re-estimating the excess supply equation for the United States at

Table 3--Actual 1984-85 (July/June) wheat trade and average free on board prices

Importers	Canada	United States	Argentina	EC-10	Australia	Other	Total
			1,000 metric tons				
Mexico	--	24	--	--	430	34	488
Brazil	1,192	3,070	604	100	--	434	5,400
Other Latin America	1,469	4,051	944	200	50	347	7,061
EC-10	1,264	945	74	--	--	0	2,283
Other Western Europe	140	618	32	900	--	0	1,690
Eastern Europe	259	74	55	1,100	--	1,114	2,602
Soviet Union	7,619	6,076	4,071	6,600	1,800	1,934	28,100
China	2,801	2,440	673	92	1,494	0	7,500
Japan	1,385	3,327	--	--	1,010	0	5,722
East, South, and Southeast Asia	622	6,309	185	552	3,373	1,329	12,370
West Asia	1,253	2,746	1,120	1,295	3,896	1,572	11,882
North Africa	950	4,657	10	3,420	2,250	1,397	12,684
Other Africa	502	2,803	126	2,068	600	51	6,150
Other	0	952	140	1,173	362	0	2,627
Total	19,456	38,092	8,034	17,500	15,265	8,212	106,559
			Dollars per metric ton				
Price, f.o.b. 1/	164	145	124	132	151	--	--

-- = Not applicable.
1/ Free on board.

Source: Foreign Agricultural Service, USDA and various issues of FATUS (3). Some adjustments were made to force exports to equal imports. EC-10 free-on-board (f.o.b.) export price was based on the border equivalent intervention price and restitution payments made.

the equilibrium price ($145 per metric ton) with 34.5 MMT as the revised base quantity. For this problem, stocks are assumed not to change.

Three features are noteworthy in comparing the base solution (table 4) with the model solution with the 5-percent production shortfall (table 5). U.S. wheat exports would fall by 5.6 percent from 38.1 MMT to 36.0 MMT, while the U.S. export price would increase by 5.4 percent from $145 per metric ton to $153 per metric ton. These changes in price and quantity imply a price elasticity of U.S. export demand of -1.04 in the short run. This arc elasticity estimate of -1.04 with the 1984/85 base is higher than the elasticity estimate of -0.70 with a 1979/81 base (2). The larger elasticity with the 1984/85 base reflects both a loss in U.S. wheat market shares between 1979/80 and 1984/85 and the inclusion of a price responsive import demand schedule for the Soviet Union. The model results indicate that shortrun U.S. export demand is nearly unitary elastic, and any policy measure that lowers U.S. export price could result in no significant change in export revenues to the United States in the short run.

Despite a 2.1 MMT fall in U.S. wheat exports, total world wheat trade falls by only 1.3 MMT, or, roughly 62 percent of the U.S. decline. Canada and

Table 4--Wheat trade flows and average f.o.b. prices, shortrun base solution

Importers	Canada	United States	Argentina	EC-10	Australia	Other	Total
			1,000 metric tons				
Mexico	--	429	25	--	--	34	488
Brazil	1,300	1,087	2,656	--	--	434	5,478
Other Latin America	--	6,096	600	--	--	347	7,043
EC-10	2,118	165	--	--	--	--	2,283
Other Western Europe	--	--	--	1,690	--	--	1,690
Eastern Europe	1,021	--	--	467	--	1,114	2,602
Soviet Union	6,000	6,000	3,600	8,720	1,800	1,934	28,054
China	2,700	2,653	673	--	1,500	--	7,526
Japan	1,300	3,522	--	--	900	--	5,722
East, South, and Southeast Asia	3,093	--	--	--	7,939	1,329	12,360
West Asia	900	7,850	300	--	1,260	1,572	11,882
North Africa	950	8,837	--	--	1,500	1,397	12,684
Other Africa	100	470	40	5,450	--	51	6,111
Other	--	952	140	1,173	362	--	2,627
Total	19,482	38,061	8,034	17,500	15,261	8,212	106,550
			Dollars per metric ton				
Price, f.o.b.	146	145	125	147	147	147	144

-- = Not applicable.

Australia would pick up some of the slack in U.S. exports by increasing their total exports by 0.51 MMT and 0.20 MMT, respectively. The U.S. export market share would fall from 35.7 to 34.2 percent, while Canadian and Australian market shares would increase slightly.

U.S. export revenue would remain roughly the same at $5.5 billion despite the increase in U.S. export price. Export revenues of Australia, Argentina, Canada, and the EC-10, on the other hand, would increase by 7, 7, 8, and 5 percent, respectively.

Most of the decline in world imports would come from the Soviet Union (0.33 MMT), China (0.25 MMT), East, South, and Southeast Asia (0.32 MMT), and other Africa (0.20 MMT). These regions would react to reduced U.S. supplies by cutting back on imports from the United States and partially compensating with more imports from other exporters. The value of world trade would increase by 4 percent from $15.38 billion to $16.02 billion in response to the production shortfall. This implies that importers, in general, would have higher import costs. The costs of imports to the Soviet Union, for instance, would increase by $17 million.

Table 5--Wheat trade flows and average f.o.b. prices for a 5-percent production shortfall by the United States

Importers	Canada	United States	Argentina	EC-10	Australia	Other	Total
			1,000 metric tons				
Mexico	--	424	25	--	--	34	483
Brazil	1,300	982	2,707	--	--	434	5,423
Other Latin America	--	5,957	600	--	--	347	6,904
EC-10	2,283	--	--	--	--	0	2,283
Other Western Europe	--	--	--	1,690	--	0	1,690
Eastern Europe	485	--	--	1,003	--	1,114	2,602
Soviet Union	6,000	6,000	3,600	8,388	1,800	1,934	27,722
China	2,700	2,400	673	--	1,500	0	7,273
Japan	2,707	2,115	--	--	900	0	5,722
East, South, and Southeast Asia	2,570	--	--	--	8,137	1,329	12,036
West Asia	900	7,850	300	--	1,260	1,572	11,882
North Africa	950	8,837	--	--	1,500	1,397	12,684
Other Africa	100	470	40	5,246	--	51	5,907
Other	0	952	140	1,173	362	0	2,627
Total	19,995	35,987	8,085	17,500	15,459	8,212	105,238
			Dollars per metric ton				
Price, f.o.b.	153	153	133	155	155	155	152

-- = Not applicable.

Trade flow patterns, per se, do not change very much. The United States would lose markets in Japan (1.4 MMT) and China (0.3 MMT). Canada would pick up the entire U.S. market loss in Japan (1.4 MMT) but would reduce its imports to Eastern Europe by 0.54 MMT. The EC-10 would increase its imports to Eastern Europe by 0.54 MMT in response. China would reduce its imports by an amount equivalent to the U.S. loss and, thus, does not increase its imports from any exporters. Argentina's and Australia's wheat shipments to the various importers would virtually be unaffected by the 5-percent shortfall in U.S. production.

Results of a 5-Percent Production Decline in the Long Run

Static spatial equilibrium models do not provide dynamic solutions that can be used to evaluate a time path of adjustment over the longer run. One means of circumventing this problem with a spatial equilibrium model is to reformulate the shortrun model with longrun excess demand and supply elasticities. The static model's results from a production shortfall as described above would then be interpreted as the impact of several years of continual production shortfalls--not the longrun results of 1 year's shortfall.

The shortrun wheat trade model is converted to a longrun model by changing the excess supply functions for Canada, United States, Argentina, and Australia. No other changes are made. In the shortrun model, the elasticity of excess supply for these exporters is a function of the price elasticities of domestic demand and ending stocks. Supply is assumed to be perfectly inelastic. For the longrun model, the elasticity of excess supply is a function of price elasticities of domestic demand and supply with ending stocks assumed not to be responsive to longrun price changes. An elasticity of supply of 0.4 is used for all regions. The price elasticity of demand is specified as -0.1 for the United States, -0.3 for Canada, and 0 for Australia.

A 5-percent U.S. production shortfall is introduced into this longrun model. The primary difference vis-a-vis the shortrun solutions is that the four price-responsive exporters adjust more to longrun price changes. As a result, the price elasticity of U.S. wheat export demand increases from -1.04 in the short run to -1.22 in the long run. In this situation, any policy measure that lowers U.S. export wheat price would result in an increase in net export revenues to the United States. However, other exporters also are more responsive to world prices, and the reduction in total world trade resulting from a U.S. production shortfall is therefore less than in the short run.

Results of Trade Liberalization by the EC-10, Japan, and the United States

EC-10, Japan, and the United States are three major participants in world wheat trade. Their domestic agricultural and trade policies, therefore, greatly affect the world wheat market. Changes in the world wheat market, on the other hand, do not necessarily fully affect their domestic markets in the short run. The EC-10, Japan, and the United States have historically pursued agricultural and trade policies that have attempted to protect their domestic wheat sector from the world market. The EC-10 uses a variable levy to maintain internal wheat prices well above the world price and disposes of excess production in the world market through restitution payments. Japan similarly maintains domestic producer prices at nearly six times the world price and uses state trading as well as licenses to restrict imports of wheat. The United States provides a variety of price and income support measures combined with land retirement programs to ensure returns to their

farmers regardless of world market conditions. These protectionist policies distort world price signals to the domestic sectors. This insulation from world price for the EC-10 and Japan is incorporated into the wheat models discussed above by assuming that the two regions will have specified quantities of net exports and imports, that is, their wheat trade is not responsive to world price movements. For the United States, the protectionist policy is introduced by ignoring supply response (potential production) on diverted land.

Trade liberalization implies a domestic sector that is fully responsive to world price, and world trade that is not constrained by bilateral agreements. It is introduced into the longrun static wheat model (1) by replacing fixed quantities of net exports and imports by the EC-10 and Japan with price responsive domestic supply and demand schedules, (2) by shifting the U.S. supply function right to represent production on land actually diverted in 1984, and (3) by removing bilateral agreements among all exporters and importers. For Japan, domestic demand elasticity of -0.1 and supply elasticity of 0.4 are used to obtain the domestic demand and supply schedules. For the EC-10, domestic supply elasticity of 0.40 and demand elasticity of -0.40 are used. For the United States, the supply function is shifted right by 10 MMT based on historical productivity of diverted land and the actual area diverted in 1984/85.

Results show that if Japan, the EC-10, and the United States were to move toward freer trade, this would reduce domestic production and increase domestic consumption in the EC-10 and Japan and conversely increase domestic production and reduce domestic consumption in the United States. Japan would import more, the EC-10 would export less, and the United States would export more (table 6).

World wheat export price would rise from $145 per metric ton to $151 in response to changes in domestic and trade policies by Japan, the EC-10, and the United States, while world wheat trade volume would remain virtually the same. The decrease in EC-10 exports is nearly offset by increases by the United States. Trade flows, however, change greatly. Without bilateral agreements, there is greater specialization. The biggest change is for Canada, which would export only to the Soviet Union. U.S. trade flows are not as greatly affected because, in the longrun base model, the United States has bilateral agreements with only two countries--the Soviet Union and China. The world wheat market would be more responsive to changes in price because of the trade liberalization initiative. The price elasticity of export demand for wheat facing the United States would rise from -1.22 under the longrun protectionist case to -2.05 in this trade liberalization scenario. Recall that the shortrun elasticity of U.S. export demand was -1.04 (table 7). With a move toward freer trade by Japan and the EC-10, international price volatility would be less than otherwise.

Japanese wheat imports would increase about 11 percent, from 5.7 MMT to 6.3 MMT, while domestic demand price would fall from $290 to $167 per metric ton (42 percent). The minimal increase in Japanese imports reflects the rather inelastic demand schedules faced by Japanese domestic consumers as well as the relatively low levels of production. Japanese agricultural policies that would allow for greater wheat imports would not, in general, greatly affect world wheat trade unless Japanese consumption habits changed dramatically.

Table 6--Estimated impact on annual world wheat trade if the EC-10, Japan, and the United States were free traders of wheat

Item	Trade volume			Trade value		
	Longrun base	Free trade	Change	Longrun base	Free trade	Change
	---1,000 metric tons----			-------Million dollars-------		
Exporters:						
United States	38,070	48,820	10,750	5,515	7,248	1,733
Canada	19,452	20,121	669	2,828	3,098	270
Australia	15,338	15,447	109	2,250	2,300	50
Argentina	8,000	8,090	90	1,000	1,028	28
EC-10	15,217	3,430	-11,787	2,239	535	-1,704
Importers:						
Japan	5,722	6,337	615	941	1,063	122
China	7,531	7,398	-133	1,249	1,227	-22
Soviet Union	28,059	27,676	-383	4,570	4,652	82
Others	62,977	62,709	-268	9,657	9,669	12
World	104,289	104,120	-169	16,417	16,611	194
			Dollars per metric ton			
U.S. export price	--	--	--	145	149	4

-- = Not applicable.

Table 7--Price elasticity of demand for U.S. wheat exports obtained with three versions of the 1984 world wheat trade model

Scenario	Elasticity at solution values
1984 trade restrictions:	
Short run	-1.04
Long run	-1.22
EC-10, Japanese, and U.S. trade liberalization:	
Long run	-2.05

These results indicate that an EC-10 move toward freer trade could greatly affect the world wheat market. EC-10 net exports would fall from 15 MMT to 3.4 MMT, a decline of over 75 percent. This decline in exports is associated with a fall in border (threshold) price from $200 per metric ton to $156. Domestic production, consequently, would fall by 9 percent and producer income would fall even more. Domestic demand would increase by 9 percent.

The United States would also be greatly affected by the trade liberalization initiative. U.S. exports would increase by 10.8 MMT, or over 28 percent, while export revenues would increase by $1.73 billion or 31 percent. The U.S. border equivalent domestic price would rise by 2.5 percent, which, when combined with production increases of 10.7 MMT, implies significant gains in gross revenue to U.S. producers. Consumers in the United States, however, would pay more and domestic demand would fall marginally.

Only Canada, among the other exporters, gains appreciably from trade liberalization. Canadian export volumes would increase by 3 percent, and export revenues by 10 percent. Australian and Argentine export volumes and values would remain virtually the same despite trade liberalization.

Importers would lose from trade liberalization as defined here. The Soviet Union, for instance, would reduce its imports from 28.1 MMT to 27.7 MMT but would pay an additional $82 million in import costs. West Asia similarly would pay an additional $250 million in import costs, 65 percent of which would be the additional transportation costs resulting from substituting Canadian and U.S. wheat for EC-10 wheat. Importers in general would obtain less for their money given increased world prices.

To conclude, a move toward freer trade in the world wheat market by the EC-10, Japan, and the United States would result in increases in producer revenues in all countries except the EC-10 and Japan. Similarly, consumers in importing countries would have to pay more for domestic consumption. The EC-10 would lose export market shares but would eliminate Common Agricultural Policy costs. The biggest gainer would be the United States.

References

(1) Holland, Forrest D. GTP: A Microcomputer Program for the Spatial Equilibrium Problem. Staff Report No. AGES850514. Economic Research Service, U.S. Department of Agriculture, Oct. 1985.

(2) Holland, Forrest D., and Jerry A. Sharples. World Wheat Trade: Implications for U.S. Exports. Staff Paper No. 84-20, Department of Agricultural Economics, Purdue University, West Lafayette, IN, Nov. 1984.

(3) Economic Research Service, U.S. Department of Agriculture. Foreign Agricultural Trade of the United States (FATUS). Various issues.