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WHEAT BUFFER STOCKS AND TRADE IN AN EFFICIENT GLOBAL ECONOMY

by

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ABSTRACT

This study assesses storage and trade of wheat in an integrated global economy. Domestic and international linkages are analyzed using a dynamic rational expectations model of the world wheat market. The results of this study demonstrate the importance of endogenizing both storage and trade in studying commodity markets. Results suggest an optimal US buffer stock level of 150 million bushel. Results indicate that past government stockholdings have not followed efficient market outcomes. Private markets likely would perform better in the absence of government market distortions. Results indicate that elimination of the Export Enhancement Program by the US and of export restitution payments by the EU is unlikely to have a major impact on wheat exports from the two regions, but will save millions of tax dollars in both regions.

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The Uruguay Round of the General Agreement on Tariffs and Trade (GATT), United States (US) farm bills (1985, 1990), and European Union (EU) MacSherry reforms are steering the world wheat market towards greater reliance on market forces. Major grain producing countries including Argentina, Australia, and Canada are liberalizing trade and implementing market-oriented farm policies. These global, regional, and domestic policy reforms have promoted freer movement of goods and services, and have made world economies more interdependent.

Global equilibrium trade models can be used to analyze trade flows among regions under the new regime, but most are not dynamic and fail to reflect the role of storage in smoothing trade flows (Bigman and Reutlinger, 1979; Bailey, 1989; Roningen, 1989; Tyers and Anderson, 1992; Johnson et al., 1993; Makki et al., 1994). Trade is not necessarily a "one shot game" as assumed by static trade models. With storage possible, the amount traded depends not only on current consumption and production but also on past and expected future consumption and production.

The modern theory of storage provides a detailed assessment of domestic market dynamics. However, it fails to endogenize trade flows among countries (Gustafson, 1958; Wright and Williams, 1982; Miranda and Helmberger, 1988; Miranda and Glauber, 1993). Modern commodity storage models have been developed to study public and private storage behavior exclusively in closed economies.

An increasingly interdependent and commercial world food market calls for an assessment of world wheat market (WWM) within a framework combining both storage and trade. Storage and trade are alternative means to smooth domestic prices and consumption in the face of unstable domestic production. In an integrated global market storage and trade respond simultaneously to food and feed shortage or surplus and to policy changes. Therefore, storage and trade flows from one country cannot be deduced independently of storage and trade in another country.

Relatively few nations account for a dominant share of the WWM exports and buffer stockholdings. The US and the EU together account for just over 50 percent of world exports, over 30 percent of world wheat stocks, and for an even larger percent of wheat buffer stocks. The present study analyzes the WWM dominated by the US and the EU in the context of the post Uruguay Round of the GATT. Domestic and international linkages in buffer stocks and trade are investigated using a dynamic rational expectations model of the WWM. The next section presents the conceptual model and the solution procedure.

I. THE MARKET MODEL

This section presents a "three-region" world wheat market consisting of two net exporters, the US and the EU, and one net importer, the combined rest-of-the-world (hereafter referred to as RW). Trade is assumed to occur between exporters and the importer, with no trade between the two exporters. For ease of exposition, the model is presented in two parts. The first part presents the model for exporters, while the second part presents the model for RW.

A. Exporters

The following conceptual model outlines market characteristics of the two exporting entities, the US and EU. The framework of supply, demand, and arbitrage conditions are similar between the US and the EU.

Material Balance. The available supply in country i in period t (A_t^i) is composed of current production (Q_t^i) plus the carryover from the last period (S_{t-1}^i). The country must allocate A_t^i among consumption (C_t^i), storage (S_t^i), and exports (X_t^i). The resulting intertemporal connection and equilibrium are summarized in the following material balance equation:

(1) $$Q_t^i + S_{t-1}^i = A_t^i = C_t^i + S_t^i + X_t^i, \quad \forall \ i = \text{US,EU}.$$

The state variable A_t^i reflects the state of the economy, which summarizes all the relevant past and current information. This specification assumes no losses in storage and no qualitative differences between the stored commodity and the freshly harvested commodity.

Consumption Demand. Current consumption, feed, and seed use in country i (C_t^i) is a downward sloping function of current market price (P_t^i) :

(2) $$C_t^i = \alpha^i (P_t^i)^{\beta^i}, \quad \forall \ i = \text{US,EU}$$

where $\alpha^i > 0$ is the constant term and $\beta^i < 0$ is the price elasticity of demand. Consumers' income is assumed to be constant in both the US and the EU[1].

[1] Even if income changed over time and the income elasticity were included in the demand function, the effects would not be large because of the low income elasticity of demand for wheat consumption in both the US and the EU.

Production. The current production in country i (Q_t^i) equals the acreage planted in the preceding year (L_{t-1}^i) times a random yield per acre (Y_t^i) :

(3) $$Q_t^i = L_{t-1}^i * Y_t^i , \quad \forall \; i = US,EU.$$

The acreage planted by rational producers in country i (L_t^i) depends on the price expected to prevail at harvest time ($E_t P_{t+1}^i$) :

(4) $$L_t^i = a^i * [E_t P_{t+1}^i]^{\eta^i} , \quad \forall \; i = US,EU \; ,$$

where $a^i > 0$ is the constant term and $\eta^i > 0$ is the price elasticity of supply in country i. Yield is assumed to be random with a known probability distribution. Neither serial correlation in yield within the region nor contemporaneous correlation in yields across regions is present. This specification is intended to capture the two salient features of agricultural production: production lags and future production uncertainty.

Storage. Storage is carried out by expected profit maximizing arbitragers. Competition among the risk-neutral stock holders eliminates speculative profits, yielding the following inter-temporal arbitrage condition[2]:

(5) $$P_t^i + k^i(S_t^i) = \delta^i * E_t(P_{t+1}^i) , \quad \forall \; i = US,EU$$

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[2] If there are efficient futures markets, then risk attitudes of stockholders will not affect their stockholding behavior. Risk attitude will affect only their positions in the futures market, not their storage behavior. Growing evidence that risk premiums are small in futures markets allows risk neutrality as a reasonable assumption (Frankel, 1984; Miranda and Helmberger, 1988; Williams and Wright, 1991)

where $\delta^i = (1+r^i)^{-1}$ is the annual discount factor when the annual interest rate is r^i, $E_t(P^i_{t+1})$ is the expectation of P^i_{t+1}, conditional on the information available in period t, and $k^i(S^i_t)$ is the marginal cost of storage. The intertemporal arbitrage condition (5) implies that, at the margin, the expected gain from holding an additional unit of stock is equal to the cost of holding it. Economic profit gained from stockholding is presumed to cause individuals and firms to pursue additional storage. This decreases expected gains and increases marginal costs, bringing equilibrium between marginal benefits and marginal costs.

The discount rate represents the opportunity cost of funds tied up in holding stocks. Storage costs, on the other hand, include cost of handling, the rental value of storage space, and insurance against theft or damage. The marginal cost of storage is specified as an increasing function of amount stored:

$$k^i(S^i_t) = k^i_1 + k^i_2 \ln(S^i_t), \quad \forall\ i = US,EU \tag{6}$$

where k_1 and k_2 are parameters. This specification of the marginal cost function allows for a *convenience yield* to storage, which represents the amount commodity processors are willing to pay to have a stable supply (Kaldor, 1939; Working, 1948, 1949; Brennan, 1958)[3]. Figure 3.1 depicts the marginal cost-of-storage function. In times of short supplies, the current price (P_t) may exceed the discounted expected price for the next year $(\delta_t\ E_tP_{t+1})$ such that there may not be any incentive for speculative carryout. When this occurs, processors will still hold contingency or working stocks to smooth production and avoid unnecessary adjustment costs.

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[3] A more general condition is when stocks are held at less than full carrying charges, which Working termed a *negative price of storage*.

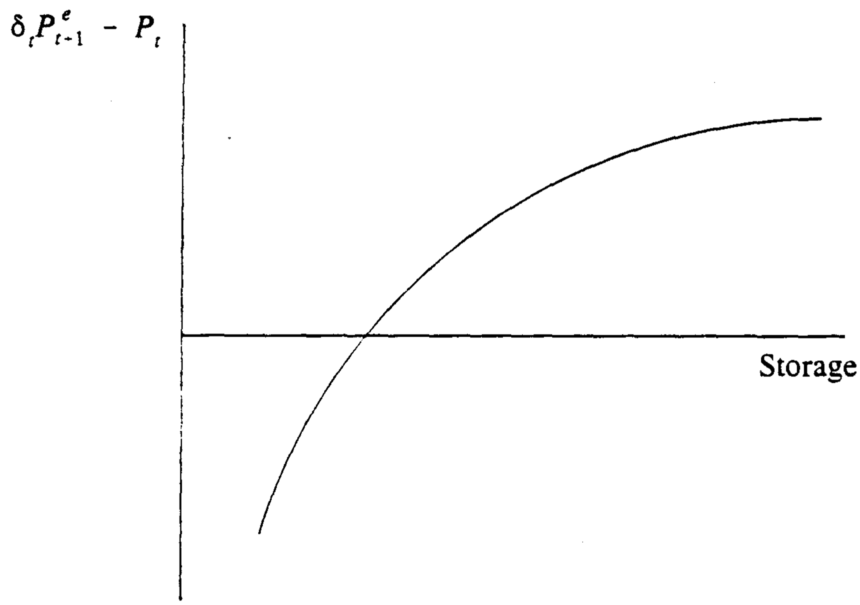

Figure 1. Supply of Storage

International Trade. International trade is undertaken by private traders who exploit spatial arbitrage profit opportunities. Competition among such traders eliminates excess arbitrage profits. Net exports from country i (X_t^i) to RW are a function of the market prices in both the regions, per unit shipping costs (τ^i), and the per unit export subsidy provided by the government (g^i). Trade is subject to the following spatial arbitrage condition:

$$(7) \qquad P_t^i + \tau^i - g^i = P_t^{rw}, \quad X_t^i > 0$$

$$P_t^i + \tau^i - g^i \geq P_t^{rw}, \quad X_t^i = 0, \quad \forall\ i = \text{US,EU}.$$

Equation (7) says that, if the buying cost plus shipping cost less government subsidy exceeds the selling price in RW, then no trade will take place. This also implies that trade takes place in one direction only, from either the US or the EU to RW.

B. Rest of the World

Rest-of-the-world is assumed to be a large consumer with no significant buffer stock holdings. It is assumed to represent the world wheat import market where the US and the EU compete to sell wheat. RW is represented by a stochastic net demand function.

Consumption Demand. Current consumption in the rest of the world (C_t^{rw}) is a function of current market price (P_t^{rw}) :

(8) $$C_t^{rw} = \alpha^{rw} * (P_t^{rw})^{\beta^{rw}} + u_t^{rw} ,$$

where the random variable u_t^{rw} is assumed to be normally distributed with mean zero and variance σ^2. Expression (8) is a net demand function. The random component, therefore, accounts for variation coming from both the supply and the demand side.

Market Clearing Condition. The model is closed by assuming the following market clearing condition:

(9) $$X_t^{us} + X_t^{eu} = C_t^{rw} ,$$

where the sum of exports from the US and the EU is equal to total consumption in the rest of the world.

C. Model Parameterization

The specific parameters presented in Table 1 are representative of the US, the EU, and RW wheat sectors. Econometric studies indicate that the price elasticity of domestic demand for wheat in the two exporting regions is approximately -0.2 (Reutlinger, 1976; Rojko et al., 1978; Gardner, 1979; Sarris and Freebairn, 1983; Tyers and Anderson, 1986; Bailey, 1989; Sullivan et al., 1989). The price elasticities of demand for major importers, as listed in Sullivan et al.,

Table 1. Model Parameters

	The US	The EU	RW
Price elasticity of demand	-0.20	-0.20	-0.31
Constant term for demand function	6.40	10.40	36.00
Price elasticity of supply	0.30	0.30	a
Constant term for supply function	0.04	0.03	a
Yield (bu per acre)	40.00	66.00	a
CV of yield[b] (%)	10.00	10.00	a
Shipping cost ($ per bushel)	0.50	0.50	a
Annual interest rate (%)	7.00	7.00	a
Storage function parameters: k_1	0.40	0.40	a
k_2	0.20	0.20	a

[a]Not relevant for RW; [b]CV is coefficient of variation obtained by dividing standard deviation by mean.

are as follows: -0.40 for North Africa, Middle East, and Southeast Asia; -0.25 for former Soviet Union; -0.10 for China; and -0.25 for the rest of the world. For the present study, the price elasticity of demand for RW is estimated to be -0.31, which is a weighted average of major importers.

Wheat supply elasticity estimates for the US and the EU reported in the literature vary widely. Sarris and Freebairn (1983) estimated a short-run wheat supply elasticity of 0.2 for the US and 0.35 for the EU; while OECD (1986) estimates were 0.5 and 0.46, respectively for the US and the EU. In the present study, a supply elasticity of 0.3 is assumed for both the US and the EU[4]. Sensitivity analysis is performed to evaluate results under alternative demand and supply elasticity estimates. The constant terms for demand and supply functions were derived using 1989-93 average price and consumption and are presented in Table 1. The random yields both in the US and the EU are assumed to be independently and identically distributed following a log-normal distribution with an estimated mean of 40 and 66 bushels per acre, respectively, and an identical coefficient of variation (CV) of 10 percent[5].

Choosing the appropriate interest rate is crucial because it represents the opportunity cost of holding stocks. Competitive stockholders must receive a rate of return on their activity at least equal to their opportunity cost. Malkeil (1990), after an extensive review of the financial literature, concluded that the real rate of return on long-term assets in the US is about 10 percent. This rate of return, however, cannot be directly used as the relevant rate of interest. Gardner (1979, p. 126) suggested that the appropriate discount rate must reflect a post-tax rate of return[6]. Assuming a tax rate of 30 percent, the appropriate rate of interest is estimated to be 7 percent. In the present study, 7 percent is used as the real rate of interest in both regions.

Storage cost function parameters are chosen such that the non-interest cost of storage lies near 10 percent of the price during normal production. International shipping costs are assumed to be $0.50 per bushel, which is approximately equal to 12.5 percent of the current price of

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[4] Gardner (1979) also used a supply elasticity of 0.3 for the US wheat.

[5] CV is standard deviation divided by mean. The estimated CVs of yield for the period 1980-93 were respectively 8.5 and 12 percent for the US and the EU. Tweeten (1994) and Ray et al. (1994) also report similar variance levels for the US and the EU, respectively.

[6] Gardner's formula is as follows: $r = R(1-t) - \dot{P}$, where r is the relevant nominal interest rate, R is the pretax nominal rate of return, t is the tax rate, and $\dot{P}$ is the rate of inflation. In the present study, however, R is real rate of return and, therefore, the inflation factor is ignored.

$4.00 per bushel (FAO predicts average shipping costs to be 10 to 15 percent of the price). Export subsidies range from $0.40 to $0.60 per bushel (US GAO, 1994). Similar parameter estimates are assumed in the EU. The random shock variable u_t in the RW demand function is assumed to be normally distributed with mean zero and standard deviation 0.1.

D. Dynamic Rational Expectations Equilibria

The goal here is to solve the market model (1) through (9) for the equilibrium functions of price, storage, exports, and acreage for the given set of parameters. Producers and stockholders, whose current actions are based on future prices, are assumed to be rational in the sense of Muth (1960). The rational expectations hypothesis implies that rational agents make forecasts consistent with those of the underlying economic model, use all available information efficiently in making decisions, and do not make systematic errors. The rational expectations hypothesis establishes a connection between the beliefs of individual agents and the actual stochastic behavior of the system. Solving a rational expectations model, thus, involves finding an equilibrium stochastic process for all the endogenous variables. The forecasts generated by this process will then be equal to the expectations that appear in the model. In this sense expectations are internally consistent with the model (Sheffrin, 1983).

The structural model developed in this study asserts that prices are related to conditional expectations. For example, if it was predicted that prices would rise by 10 percent by the end of the year, stockholders would accumulate stocks until the expected marginal returns from holding stocks equates the cost of storage. Thus no patterns established from past behavior can ever be used to predict future price behavior. The study uses stochastic dynamic programming to solve for the equilibrium stochastic process of endogenous variables. The inability of storage to work backwards introduces a nonlinearity into the system requiring numerical methods to implement the stochastic dynamic programming[7].

The polynomial projection and collocation method is used to solve for the competitive equilibrium conditions (Judd, 1991; Miranda, 1994; Miranda and Glauber, 1993). In this method the expected price functions are approximated using a Chebychev polynomial and conditional expectations are computed using Gaussian quadratures. The equilibrium functions are computed by successive approximation and the steady state values and the dynamic paths are generated by the Monte Carlo simulation method. For details see Makki (1995).

II. STORAGE-TRADE INTERDEPENDENCE

The introduction of storage into a trade model alters the relationship between supply and demand, and, hence, price behavior. The dynamic rational expectations model explicitly recognizes that the market as a whole cannot carry negative stocks, thus introducing nonlinearity in the supply-storage relationship. This nonlinearity extends itself to price-quantity relationships shown with and without storage in Figure 2. The quantity on the horizontal axis is composed of demand for consumption, storage, and exports. The nonlinearity in the price-quantity relationship occurs at the point at which storage first occurs (A_0). The figure indicates that endogenizing storage in a trade model augments the demand curve and makes price less sensitive to quantity changes.

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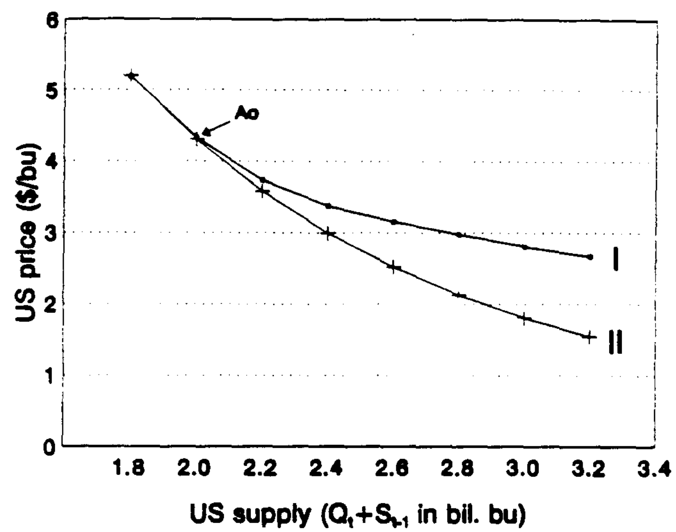
[7] The impossibility of carrying forward negative stocks imposes a non-negativity constraint on stocks, which has been an important feature of more recent literature on commodity storage (Miranda and Helmberger, 1988; Williams and Wright, 1991; Miranda and Glauber, 1993).



Note: EU wheat supply is held constant at 2.4 bil. bu.

Figure 2. Equilibrium Price Functions for US Wheat With (I) and Without (II) Storage

The steady-state distributions of price and consumption were also different in the absence of storage (Table 2). For example, with no storage possible, the coefficient of variation of price was 35 percent compared to 20 percent when storage is endogenous. The coefficient of variation of consumption was also lower with storage (3 percent) than without storage (7 percent). Thus, storage helps to stabilize both price and consumption.

Another result, evident from Table 2, is that the coefficient of variation of price in the importing region RW is lower with storage (17 percent) compared to no storage (30 percent) in the two exporting countries. Results also indicate that RW consumers, on average, pay more when no storage is undertaken in the two exporting countries. The coefficient of variation of consumption in RW was 5 percent with storage and 10 percent without storage. Thus storage in exporting countries provides an externality in the form of more stable consumption and lower and more stable prices for importers.

Table 2. Steady State Mean and Coefficient of Variation (CV) of Price, Consumption, Storage, Exports, Acreage, and Production With and Without Storage.

		With Storage		Without Storage	
Region	Variables	Mean	CV(%)	Mean	CV(%)
US	Price ($/bu)	3.38	19.57	3.44	34.85
	Consumption (mil. bu)	1256.76	3.40	1264.93	6.89
	Storage (mil. bu)	148.93	80.43	ns	ns
	Exports (mil. bu)	1177.32	17.51	1187.02	19.49
	Acreage (mil. acre)	60.50	1.03	60.89	2.31
	Production (mil. bu)	2437.91	12.15	2453.66	12.01
EU	Price ($/bu)	3.38	19.57	3.44	34.85
	Consumption (mil. bu)	1301.76	3.40	1310.22	6.89
	Storage (mil. bu)	148.93	80.43	ns	ns
	Exports (mil. bu)	1046.80	19.37	1056.15	21.27
	Acreage (mil. acre)	38.89	1.02	39.15	2.01
	Production (mil. bu)	2350.99	12.20	2366.18	12.06
RW	Price ($/bu)	3.88	17.05	3.94	30.43
	Consumption (mil. bu)	2224.13	4.89	2243.19	9.85

Note: ns. No storage.

A. Competitive Storage

Total stockholdings in an economy can be divided into three types: (i) *Buffer stocks* are held to provide for contingencies (precautionary motive) and to take advantage of unforseen (speculative) opportunities to make profits; (ii) *seasonal stocks* are generally held to smooth consumption from one harvest to the next; and (iii) *pipeline stocks* are held by distributors of the commodity in transit, in processing, and on store shelves. The present study estimates only buffer stockholdings. Seasonal and pipeline stocks have little impact on market behavior in the long-run and hence are not analyzed in this study. However, pipeline stocks must be added to buffer stocks shown herein in comparing actual with efficient market year-end carryover stocks[8].

Table 2 suggests an optimal buffer stock level of 150 million bushels in the US if the coefficient of production is 10 percent and discount factor is 7 percent in both the US and in the EU. This level will change depending on the domestic and foreign level of production instability, interest rates, and government commodity programs[9]. For example, a US-EU coefficient of variation of production of 15 percent with zero discount rate calls for US wheat buffer stocks of 262 million bushels - a figure close to actual numbers from 1991 to 1994 if pipeline stocks are included.

Figure 3 indicates the competitive equilibrium storage levels for the US under alternative supply levels in the EU. This relationship, generally referred to as a "rule" in the commodity

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[8] Tweeten (1994) estimated a pipeline stock level of 250 million bushels of wheat in the US in 1991-92.

[9] Gardner (1979) in his analysis of US wheat market indicated that in a free market with no government storage, the private sector, on average, would hold a speculative stock level of 180 million bushels of wheat.

storage literature, explains the functional relationship between economic states and equilibrium levels of stocks. For example, the competitive storage rule indicates that, with a beginning supply in the US of 2.6 billion bushels, a profit maximizing, rational competitive US storage industry would hold 167 million bushels in buffer stocks when the available supply in the EU is 2.4 billion bushels and would hold 303 million bushels when the available supply in the EU is 2.8 billion bushels (Figure 3). If the beginning supply in the US were 3.0 billion bushels, competitive stockholding would be 303 and 445 million bushels, respectively for the above levels of supplies in the EU. These rules indicate that the buffer stock in the US increases as the available supply in the EU rises. Thus stockholdings in the US and the EU are interdependent.

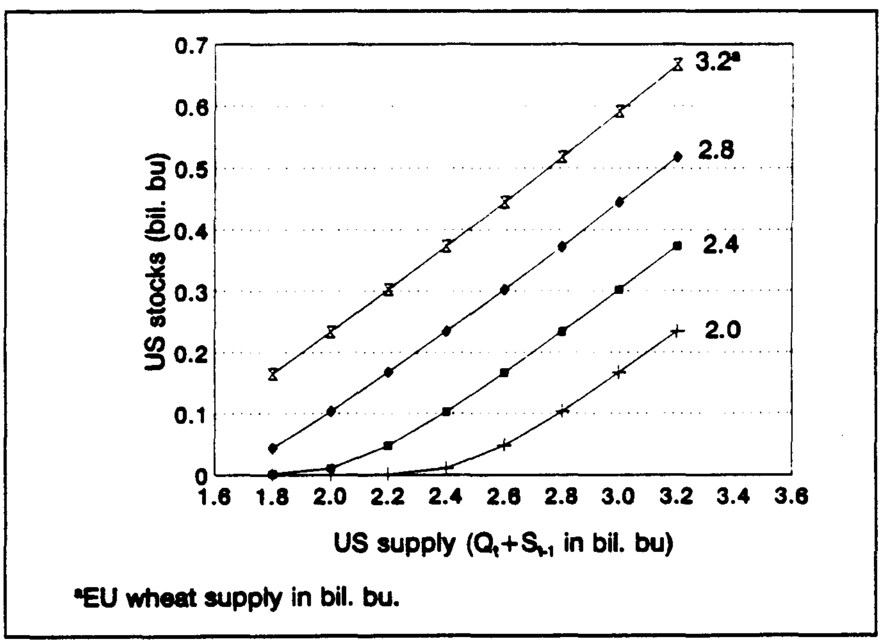

Figure 3. Equilibrium Storage Rules for US Wheat Under Alternative Supply Levels in the EU.

Higher levels of supply in the EU reduce the current price in both the regions, which in turn induces rational stockholders to accumulate stocks in both regions[10].

The expected equilibrium storage levels generated by this model approximate the optimal level of stockholdings in a well functioning economy. These results represent the behavior of private stockholders maximizing profit or a public stockholding agency minimizing deadweight loss to the economy. The generated rules, therefore, provide the benchmark for both public and private buffer stock operations.

B. Competitive Trade

Figure 4 illustrates equilibrium wheat exports from the US under alternative supply levels in the EU. In contrast to equilibrium storage functions, the equilibrium export functions shift downward (exports decline) with a larger EU supply. A larger EU supply diminishes US exports and raises US stocks, *ceteris paribus*. Thus buffer stocks and exports are substitutes when the market is open and efficient.

In conclusion, our findings indicate that equilibrium levels of trade are sensitive to the presence of storage. Having demonstrated the significance of storage-trade interdependence in commodity markets, we now examine how storage and trade respond to policy changes.

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[10] In the present study equilibrium stock levels in the US and the EU are simultaneously determined. If the EU were to hold stocks autonomously, then the rational stockholders in the US would decrease their stockholdings when the EU increases its stock level and *vice versa*.

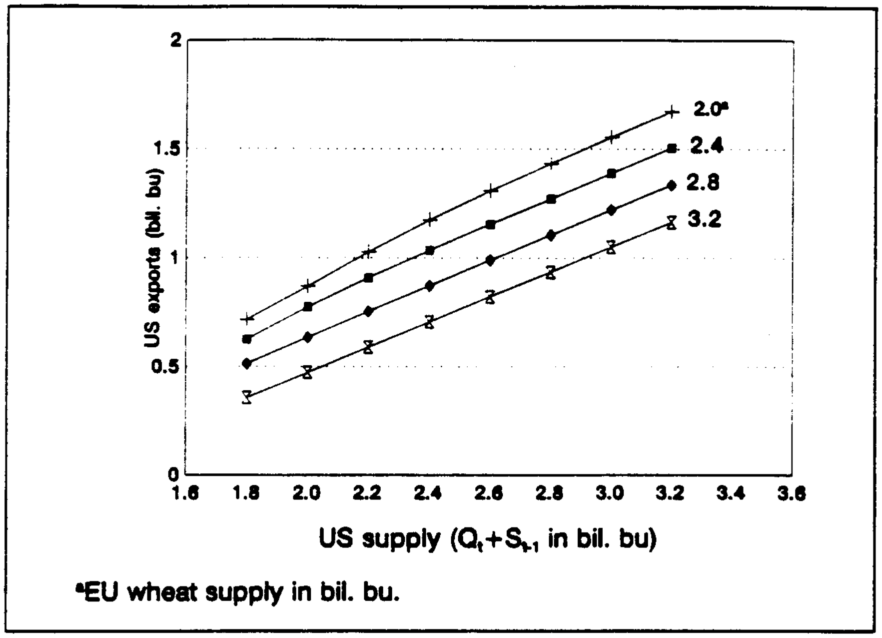

Figure 4. Equilibrium Exports Rules for US Wheat Under Alternative Supply Levels in the EU.

III. STORAGE-TRADE RESPONSE TO A REDUCTION IN EXPORT SUBSIDIES

The US government introduced the Export Enhancement Program (EEP) in 1985 to stabilize and increase exports, and to reduce record stock levels accumulated during the early 1980s. The EEP was a counteroffensive strategy to hold market share by countering EU export subsidies. Under the program, government-owned surplus agricultural commodities were made available as bonuses to US exporters to enable them to lower export prices of US agricultural commodities and make them competitive with subsidized foreign exports, particularly those subsidized by the EU (US GAO, 1994).

Since its inception in 1985 through March 1994, over $6.3 billion of US agricultural commodities have been made available as bonuses to eligible US exports. Nearly 80% of the EEP budget supported wheat sales during those years. The EEP subsidy during the entire period was estimated to average $0.50 per bushel (US GAO, 1994). In the case of the EU, restitution payments to exporters make up the difference between the intervention price and the world price. The net effect of the export restitution payments is assumed to be similar to that of the EEP.

According to the recently signed GATT agreement, the quantity of subsidized exports is to be cut by 21 percent, and export subsidy value is to be reduced by 36 percent over the next six years. The wheat subsidy is expected to fall to $0.20 per bushel when the GATT agreement is fully implemented. Table 3 reports the steady state mean and coefficient of variation of price, consumption, storage, exports, acreage, and production of wheat in response to a partial, a unilateral, and a multilateral removal of the EEP and EU export restitution payments. Table 4 presents the estimated economic benefits/losses from such policy shifts. A 36 percent reduction in export subsidies in both regions is predicted to have only a modest impact on US exports because the US and the EU liberalizations tend to offset each other. The simulated results show that US wheat exports fall by 14 million bushels or 1.2 percent, while wheat stocks rise by 2 million bushels or 1.2 percent (Table 3). US export revenue is expected to fall by $110 million but the predicted savings from a reduced EEP budget would be $219 million (Table 4). US consumers would gain ($78 million) while producers would lose ($160 million) due to partial liberalization. The GATT agreement, therefore, would save the US economy $136 million[11].

[11] Results and policy implications for the EU are analogous to that of the US and hence not explicitly discussed to save space.

Table 3. Steady State Mean and Coefficient of Variation of Price, Consumption, Storage, Exports, Acreage, and Production of Wheat Under Alternative Export Subsidy Policies of the US and the EU.

	Current Policy[a]		Partial[b]		Unilateral[c]		Multilateral[d]	
Variables	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)
The US								
Price ($/bu)	3.51	18.54	3.46	18.93	3.35	19.76	3.38	19.57
Consumption (mil. bu)	1246.52	3.24	1250.29	3.30	1258.72	3.42	1256.76	3.40
Storage (mil. bu)	144.31	81.02	146.04	80.82	149.79	80.30	148.93	80.43
Exports (mil. bu)	1215.97	17.26	1201.66	17.35	1170.00	17.55	1177.32	17.51
Acreage (mil. acre)	61.22	1.01	60.95	1.01	60.37	1.00	60.50	1.03
Production (mil. bu)	2466.83	12.13	2456.09	12.04	2432.45	12.15	2437.91	12.15
The EU								
Price ($/bu)	3.51	18.55	3.46	18.93	3.48	18.76	3.38	19.57
Consumption (mil. bu)	1291.15	3.24	1295.06	3.29	1293.34	3.27	1301.76	3.40
Storage (mil. bu)	144.31	81.02	146.04	80.81	145.28	80.92	148.93	80.43
Exports (mil. bu)	1084.79	19.01	1070.72	19.14	1076.92	19.08	1046.80	19.37
Acreage (mil. acre)	39.36	1.01	39.18	1.01	39.26	1.01	38.89	1.02
Production (mil. bu)	2378.88	12.18	2368.53	12.18	2373.08	12.18	2350.99	12.20
RW								
Price ($/bu)	3.51	18.54	3.74	17.99	3.76	17.76	3.88	17.05
Consumption (mil. bu)	2300.78	5.30	2272.39	5.15	2246.92	5.01	2224.13	4.89

[a]Current policy uses an export subsidy of $0.50 per bushel in both regions; [b]Both the US and EU cut export subsidy value by 36%; [c]The US unilaterally eliminates the EEP and the EU cuts by 36%; [d]No export subsidies in either region.

Table 4. Expected Economic Gains/Losses from Removing Export Subsidies (in million dollars)

	Partial[a]	Unilateral[b]	Multilateral[c]
US			
Consumer Surplus	+ 77.92	+ 251.83	+ 204.11
Producer Surplus	- 160.50	- 509.86	- 418.44
Taxpayers Savings	+ 218.87	+ 607.98	+ 607.98
Net National Gain	+ 136.29	+ 349.95	+ 393.65
EU			
Consumer Surplus	+ 83.23	+ 49.85	+ 218.03
Producer Surplus	- 154.75	- 91.55	- 403.52
Taxpayers Savings	+ 195.26	+ 195.26	+ 542.40
Net National Gain	+ 123.74	+ 153.56	+ 356.91
RW			
Consumer Surplus	- 1331.80	- 1430.49	- 2087.91

[a]Both the US and the EU cut export subsidy value by 36 percent.
[b]The US unilaterally eliminates the EEP and the EU cuts export subsidy value by 36 percent.
[c]No export subsidies in either region.

What if the EU adheres to the GATT requirements of 36 percent reduction in export subsidies and the US unilaterally removes all export subsidies? Unilateral elimination of export subsidies by the US would decrease its exports by 4 percent and increase its stocks by 4 percent from the current policy (Table 3). US wheat prices would fall by 16 cents per bushel or 5 percent while consumption would increase by 12 million bushels or 1 percent. Unilateral removal of export subsidies would benefit consumers ($252 million) and cost producers ($510 million). But it would save the US economy $350 million (Table 4).

Results show that multilateral elimination of export subsidies would decrease US exports by 3 percent and increase wheat stocks by 3 percent (Table 3). The difference between results from unilateral versus multilateral removal of export subsidies is small. Results also indicate that the domestic price of wheat would decrease by 4 percent while consumption would increase by 1 percent after the subsidies are completely eliminated. The world price is predicted to rise slightly and become less volatile. These findings are consistent with some of the previous literature examining the efficacy of EEP (Bailey and Houck, 1990; Brooks, Devadoss and Meyers, 1990; Seitzinger and Paarlberg, 1990). Bailey and Houck, using a dynamic nonspatial equilibrium model of world wheat market, indicated that the EEP plays a minor role in expanding US exports. Seitzinger and Paarlberg attributed 2 to 3 percent expansion in exports to the EEP.

Table 4 shows that producers are less worse off with multilateral compared to unilateral policy change. Unilateral more than multilateral elimination of all export subsidies dampens the domestic price. The net benefit to the US economy from multilateral removal of export subsidies is estimated to be $394 million. Results also show the inefficiency of the EEP. Each EEP dollar increases US exports by only $0.50. Thus deficiency payments paid directly to producers are more cost-effective than export subsidies in raising farm income.

The foregoing analysis reveals the dynamic response of storage and trade to the EEP and EU restitution payments in the face of changing market conditions. The results suggest that elimination of export subsidies will not have a major impact on world wheat trade but will save millions of dollars for taxpayers.

IV. STORAGE-TRADE RESPONSE TO INTEREST RATES

This section examines the impact of changes in real interest rates (discount rates) on storage and trade. The discount rate accounts for the risk and opportunity cost of holding stocks. For a given level of supply, private storage will tend to be larger the lower the discount rate. High discount rates constrain private sector stock holding.

Table 5 reports the steady-state properties of selected endogenous variables for different interest rates. Results show that the steady-state storage in the US decreased by 29 million bushels or 19 percent when the interest rate increased from 7 to 10 percent. When the storage level decreases the market becomes more volatile. The coefficient of variation of prices increased by 2 percentage points in all three regions in response to an increase in interest rate from 7 to 10 percent. The coefficient of variation in consumption, however, changes little. Consumption in both the US and the EU declined by a million bushel each, while consumption in RW increased by 2 million bushels. The small changes in mean and CV of consumption is because of low elasticity of demand for wheat in the US and in the EU. US wheat exports increased by a million bushel in response to an increase in interest rate from 7 to 10 percent.

Figure 5 graphs the steady state mean stocks in the US for different interest rates. The propensity to hold buffer stocks decreases as the interest rate increases. Mean stocks decreased from 225 million bushels to 120 million bushels in response to an increase in the interest rate from zero to 10 percent in the US and EU. Lower stock levels increase market price volatility. Figure 6 shows the relationship between the world interest rate and the CV of US wheat prices. The CV of price increased from 15 percent to 22 percent in response to an increase in the interest rate from zero to 10 percent in all regions of the world.

Table 5. Steady State Mean and Coefficient of Variation of Price, Consumption, Storage, Exports, Acreage, and Production of Wheat Under Alternative Interest Rates[a].

	Interest Rates					
	3 percent		7 percent		10 percent	
Variables	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
US						
Price ($/bu)	3.37	17.19	3.38	19.57	3.39	21.64
Consumption (mil. bu)	1256.04	3.01	1256.76	3.40	1257.45	3.74
Storage (mil. bu)	188.93	70.81	148.93	80.43	119.92	89.81
Exports (mil. bu)	1176.30	17.30	1177.32	17.50	1178.15	17.70
Acreage (mil. ac)	60.48	0.91	60.50	1.03	60.53	1.11
Production (mil. ac)	2436.95	12.15	2437.91	12.15	2439.05	12.14
EU						
Price ($/bu)	3.37	17.19	3.38	19.57	3.38	21.64
Consumption (mil. bu)	1301.02	3.01	1301.76	3.40	1302.48	3.74
Storage (mil. bu)	188.93	70.81	148.93	80.43	119.92	89.81
Exports (mil. bu)	1046.00	19.20	1046.80	19.37	1047.65	19.52
Acreage (mil. bu)	38.88	0.89	38.89	1.02	38.91	1.11
Production (mil. bu)	2350.07	12.20	2350.99	12.20	2352.09	12.19
RW						
Price ($/bu)	3.87	14.97	3.88	17.05	3.88	18.86
Consumption (mil. bu)	2222.32	4.34	2224.13	4.89	2225.82	5.39

[a]Interest rates are equal and change simultaneously in all regions.

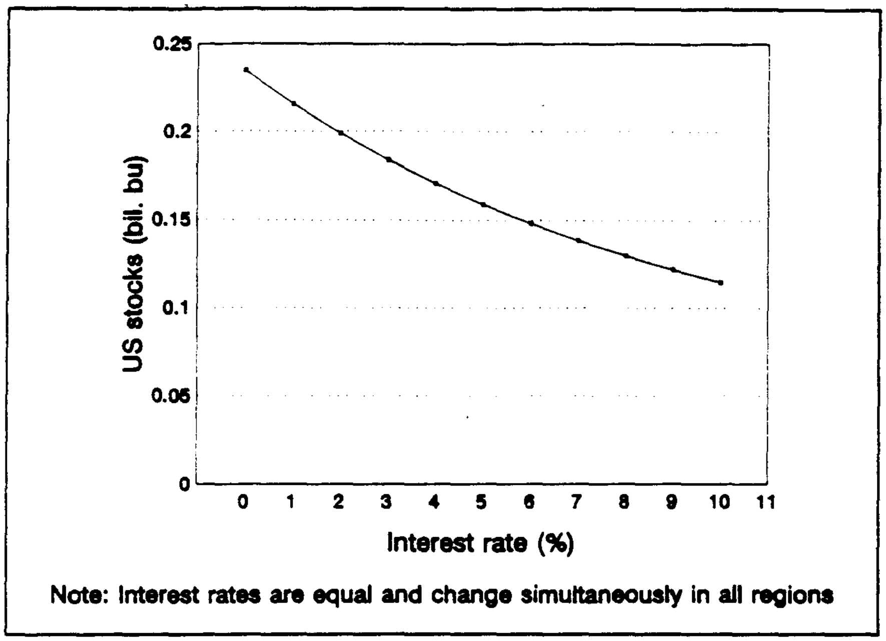

Figure 5. Predicted Effect of World Interest Rates on US Wheat Stocks

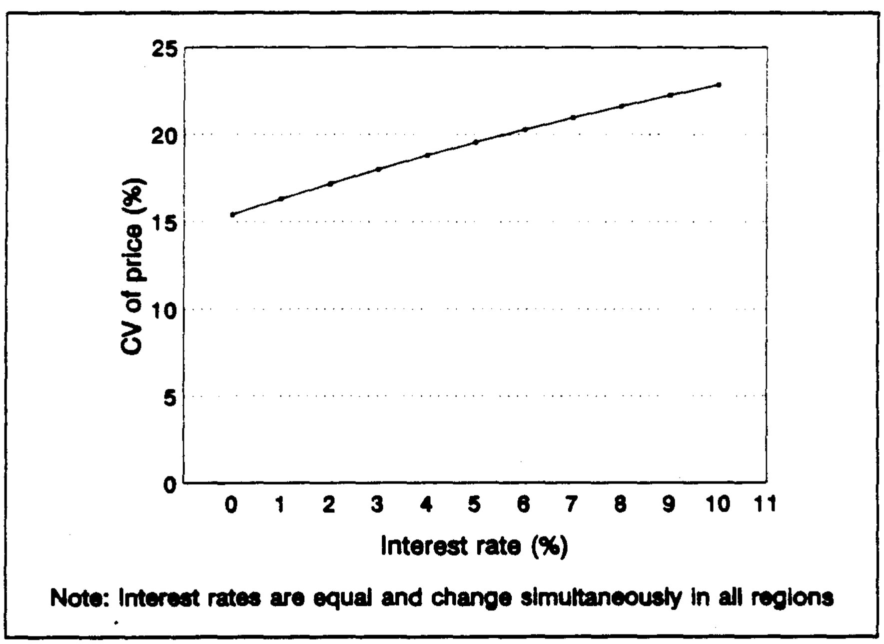

Figure 6. Predicted Effect of World Interest Rates on CV of US Prices

Underlying discount factors can differ between public and private storage, chiefly due to the differences in opportunity costs of capital and risks involved in maintaining stocks. The discount factor is lower for public stocks because the public sector can spread its risks over time, over many investments, and over the entire taxpaying population such that each citizen would bear only a negligible share of the total risk. Private stockholders require higher rates of return to compensate for high perceived risks of stockholding. Private stockholders are likely to pay higher interest rates on borrowed funds and often face attractive alternative investment opportunities. Hence the lower public discount rate justifies holding more stocks than would the private sector. However, the potential social gain from public stockholdings must be balanced against the shortcomings of public stocks. The public sector may mismanage stocks as evident from excessive grain stocks gathered by US commodity programs in past years.

Assuming an interest rate of 3 percent for the public sector, the estimated efficient stock level was 189 million bushels, or about 27 percent higher than stocks held solely by the competitive market at an interest rate of 7 percent (Table 5). Private stockholding may also be reduced by the prospect of unpredictable government intervention in markets in response to political pressures.

Table 6 illustrates how increases in interest rates in one country affect equilibrium price, consumption, storage, exports, acreage, and production in all regions. This analysis assesses the impact of increases in the interest rates in the US in 1994 and 1995, *ceteris paribus*. Results indicate that buffer stocks in the US decrease by 31 percent, while stocks in the EU increase by 12 percent when the interest rate in the US is increased from 7 to 10 percent, holding the

Table 6. Impact of Higher US Interest Rates on World Wheat Market[a].

	Interest Rates					
	8 percent[b]		9 percent		10 percent	
Variables	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
US						
Price ($/bu)	3.37	19.93	3.38	20.25	3.38	20.52
Consumption (mil. bu)	1256.88	3.45	1256.99	3.50	1257.09	3.55
Storage (mil. bu)	132.18	82.39	117.00	84.26	103.27	86.07
Exports (mil. bu)	1177.61	17.69	1177.87	17.91	1178.11	18.15
Acreage (mil. ac)	60.51	1.01	60.51	1.01	60.52	1.01
Production (mil. ac)	2438.10	12.15	2438.28	12.15	2438.45	12.14
EU						
Price ($/bu)	3.38	19.93	3.38	20.25	3.38	20.52
Consumption (mil. bu)	1301.86	3.45	1301.95	3.51	1302.04	3.55
Storage (mil. bu)	155.21	81.50	161.30	82.50	167.15	83.43
Exports (mil. bu)	1046.78	19.31	1046.78	19.30	1047.60	19.32
Acreage (mil. bu)	38.90	1.01	38.90	1.01	38.90	1.01
Production (mil. bu)	2351.17	12.20	2351.34	12.20	2351.51	12.19
RW						
Price ($/bu)	3.88	17.36	3.88	17.64	3.88	17.88
Consumption (mil. bu)	2224.41	4.98	2224.66	5.05	2224.88	5.11

[a]Interest rate changes only in the US; interest rate in the EU is held steady at 7 percent.
[b]For base period (7 percent interest rate) refer to Table 5.

interest rate in the EU steady at 7 percent. Results suggest that for every bushel decrease in US stocks, the EU will increase its stockholdings by 0.4 bushels.

Figure 7 graphically illustrates the shifts in equilibrium storage rules in response to increases in US interest rates. The figure shows that equilibrium stocks shift downward in the US and upward in the EU when interest rates in the US alone increase. US interest rate hikes restrain holding of buffer stocks and increase the volatility of commodity markets. Grain stocks in the EU increase to compensate for less US stocks. The impact of higher US interest rates on price and other variables is small.

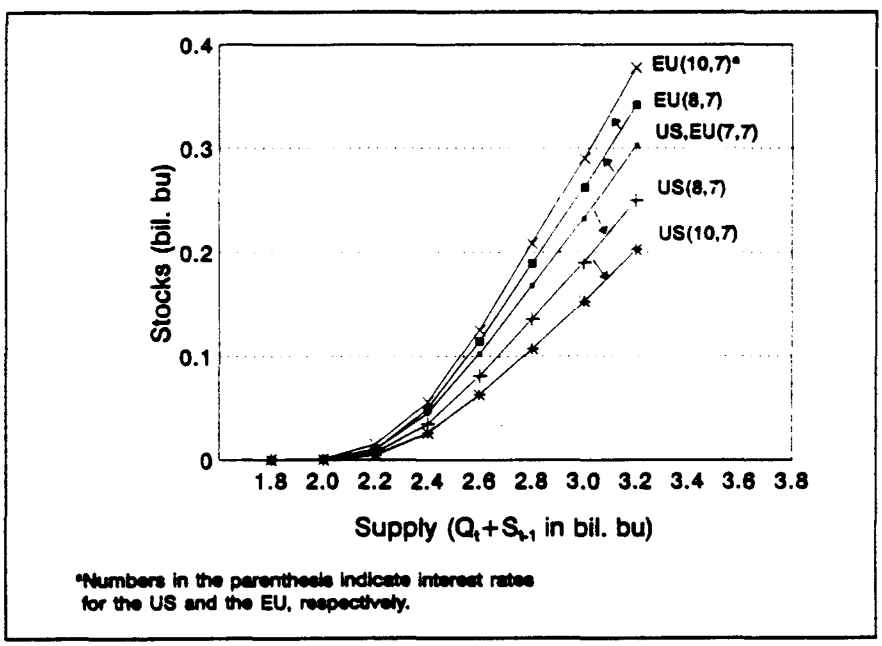

Figure 7. Equilibrium Storage Rules for the US and the EU Under Increasing Interest Rates in the US

V. PARAMETER SENSITIVITY ANALYSIS

Sensitivity analysis of equilibrium model parameters is critical for establishing the robustness of model results. Demand and supply elasticities are key parameters and hence are of special concern. In the following simulations demand and supply elasticities for the US and the EU are changed jointly while the elasticity of demand in RW is held constant at -0.31.

A. Sensitivity to Elasticity of Demand

The higher the price elasticity of demand, the lower the marginal propensity to hold stocks. This is because a more elastic or relatively flat demand curve causes price to be less sensitive changes in supply, reducing the incentive for holding stocks. With an elastic demand, consumers absorb most of the variation in production by adjusting their consumption, making price stability provided by storage less necessary.

Table 7 summarizes the steady state properties of price, consumption, storage, exports, acreage, and production under different demand elasticities. The selected elasticities range from -0.1 to -0.4. The table indicates that storage is relatively more sensitive than are other endogenous variables to changes in demand elasticities. For example, mean storage decreased from 156 million bushels to 124 million bushels or 21 percent in response to an absolute value increase in elasticity from -0.1 to -0.4. The coefficient of variation of stocks increased from 79 percent to 82 percent for a similar increase in the elasticity of demand.

The results indicate that US exports increased by 50 million bushels or 4 percent when the elasticity of demand increased from -0.1 to -0.4 (Table 7). The changes in the coefficient of variation of exports were small.

Table 7. Sensitivity to Demand and Supply Elasticities: Steady State Mean and Coefficient of Variation (CV) of Price, Consumption, Storage, Exports, Acreage, and Production of Wheat in the US[a].

		Price ($/bu)	Consumption (mil. bu)	Storage (mil. bu)	Exports (mil. bu)	Acreage (mil. acre)	Production (mil. bu)
Demand Elasticity							
-0.1	Mean	3.36	1258.02	156.35	1170.67	60.71	2412.14
	CV (%)	21.26	2.76	79.06	17.41	0.70	12.18
-0.2	Mean	3.38	1256.76	148.93	1177.32	60.50	2437.91
	CV (%)	19.57	3.40	80.43	17.50	1.01	12.15
-0.3	Mean	3.22	1179.81	134.22	1220.62	59.65	2403.40
	CV (%)	16.76	4.51	81.03	16.64	1.01	12.11
-0.4	Mean	3.27	1191.39	124.11	1220.24	59.93	2414.69
	CV (%)	14.81	5.39	81.65	16.62	1.01	12.09
Supply Elasticity							
0.1	Mean	3.65	1236.88	149.39	1146.52	59.22	2386.32
	CV (%)	21.63	3.78	78.04	17.47	0.91	12.04
0.3	Mean	3.38	1256.76	148.93	1177.32	60.50	2437.91
	CV (%)	19.57	3.40	80.43	17.50	1.01	12.15
0.5	Mean	3.37	1259.97	148.35	1182.35	60.69	2464.74
	CV (%)	19.37	3.31	80.46	17.70	1.01	12.16
1.0	Mean	3.06	1282.80	147.83	1190.17	61.50	2478.13
	CV (%)	18.28	3.16	81.76	17.61	1.11	12.31

[a]Elasticity parameters are identical for both the US and the EU and change simultaneously in both the regions; elasticity of demand in RW is held constant at -0.31.

As expected, the higher the price elasticity of demand the smaller the domestic price instability. For example, the coefficients of variation of price decreased from 21 percent to 15 percent in response to an increase in demand elasticity from -0.1 to -0.4 (Table 7). The coefficient of variation of consumption in the US, on the other hand, increased modestly (from 3 to 5 percent) for a similar increase in demand elasticity.

These simulations indicate that the model results are relatively robust to changes in the elasticity of demand. In general, the magnitude of change in simulated results for changes in price elasticity of demand was small.

A more liberalized market is generally associated with higher elasticities. The results of this study suggest that a more liberalized global economy will face lower price variability, reducing the need for buffer stocks. Freer markets also encourage more trade and that trade is less volatile. The CV of consumption increases modestly in more open economies (Table 7).

B. Sensitivity to Elasticity of Supply

Rational stockholders carry forward less stock if they expect producers to increase production in response to higher prices; rational producers respond to future production uncertainties by adjusting the planting area. The supply elasticity determines the degree of flexibility that farmers have in responding to future expectations. A more flexible supply response substitutes for grain stocks. Thus, as the supply elasticity increases, storage becomes less important as responsive production complements storage in stabilizing prices and consumption.

Table 7 presents the steady state mean and coefficient of variation of price, consumption, storage, exports, acreage, and production of wheat in the US for selected supply elasticities ranging from 0.1 to 1.0. The coefficient of variation of price and consumption declines marginally as the elasticity of supply is increased from 0.1 to 1.0. The decline in steady state mean stockholding is small. The conclusion from Table 7 is that means and coefficients of variation of key variables are not highly responsive to changes in demand and supply elasticities within the ranges examined.

VI. CONCLUSIONS

This study developed a structural model of the world wheat market consisting of the US, the EU, and a combined rest-of-the-world. The model assesses domestic and international linkages in buffer stockholdings and trade of wheat in an efficient, integrated global economy characterized by stochastic production in the US and the EU. RW is represented by a stochastic net demand function which accounts for both stochastic production and stochastic consumption in RW. The rational expectations framework was used to incorporate the effects of future uncertainty on stockholding behavior and on market prices. The major findings of this study are summarized below.

First, the results of the present study suggest an optimal wheat buffer stock level of 150 million bushels in the US if the coefficient of variation in production is 10 percent and discount factor is 7 percent in both the US and in the EU. This level will change depending on the domestic and foreign level of production instability, supply, interest rates, government commodity programs, and foreign stockholdings. Adding pipeline stocks of 250 million bushels still leaves optimal US carryover stocks of 400 million bushels, well below stock levels of the 1950s and 1960s under commodity programs. However, the optimal buffer stock level increases to 262 million bushels if the discount factor is reduced to zero and CV of production is increased to 15 percent, which is approximately equal to the actual level of stocks held by the US in recent years (when pipeline stocks are added) but much lower than stocks of the 1950s and 1960s. So it is possible to rationalize the recent levels of buffer stocks but not those of the 1950s and 1960s held for extended periods with help from the CCC. Reliance on private stocks alone is likely to result in more efficient buffer reserve levels than did past government stockholdings.

Second, higher US interest rates reduce optimal US wheat buffer stocks but could be compensated by the increased stock levels in the EU. Results predict that for every bushel decrease in US stocks, the EU will increase its stocks by 0.4 bushels.

Third, results indicate that elimination of the Export Enhancement Program by the US and export restitution payments by the EU is unlikely to have a major impact on wheat exports from the two regions, but will save millions of dollars to taxpayers in both the regions. Any decrease in exports is unlikely to markedly reduce market prices in the US because in the short run a large part of reduced exports will be held as stocks.

Fourth, each $1 cut from EEP on average would reduce US wheat producers' net income by an estimated $0.69 to $0.84 while raising the real income of consumers by $0.34 to $0.41 and real national income by $0.58 to $0.65. Thus direct payments to producers would be more cost effective means than EEP to raise US farm income.

The EU has held large stocks of wheat in some recent years. But policy reforms of the EU as well as the US have attempted to reduce wheat stocks. Global wheat stocks at the end of the 1995/96 marketing year are expected to set record lows for recent decades. The private sector is unlikely to hold much buffer stocks because the stockholding and marketing intentions of the US and EU public sectors are unclear. Thus during the precarious transition currently underway to a more market oriented agriculture and liberalized trade, the government may need to hold at least a modest size emergency wheat reserve to provide a backup to private stockholding.

It is possible that risk neutrality and other assumptions of this model do not hold in reality. If consumers are highly risk averse, then the private sector alone will not provide adequate wheat reserve stocks. Other shortcomings of the model include failure to endogenize related sectors such as rice and coarse grains, and to account for other wheat producing nations such as those in the southern hemisphere diminishing the need for US stocks.

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