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ABSTRACT

Adverse weather factors in India augment the instability in wheat supply and trade. Consequently, India's wheat trade is a classic example of stochastic supply being the dominant factor in determining trade flows. This study analyses the effects of random fluctuations in India's wheat supply on domestic and world price variability and trade flows of India and major exporters and importers by using stochastic simulation analysis. Production instability causes price variability of $71 per metric ton under autarky condition. However, price variability is mitigated once trade is allowed. Thus, trade acts as a buffer stock program in reducing price variability. The results show that production shortfalls (surpluses) in India benefit wheat exporters (importers) and hurt importers (exporters).

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I. Introduction

Various trade theories, from Adam Smith's absolute advantage theory to Vernon's product life cycle theory, have emphasized such factors as marketing institutions, government policies, exchange rates, natural resource endowments, factor proportions, production efficiency, and technological development as important determinants of a country's trade potential. However, random fluctuations in supply, particularly in agricultural commodities, have had significant impacts on the trade flows, but has received scant attention in the literature. For example, Bigman (1982) elucidates that supply fluctuation is an important factor in determining the trade flow, which is unexplained and unaccounted by the standard trade theories.

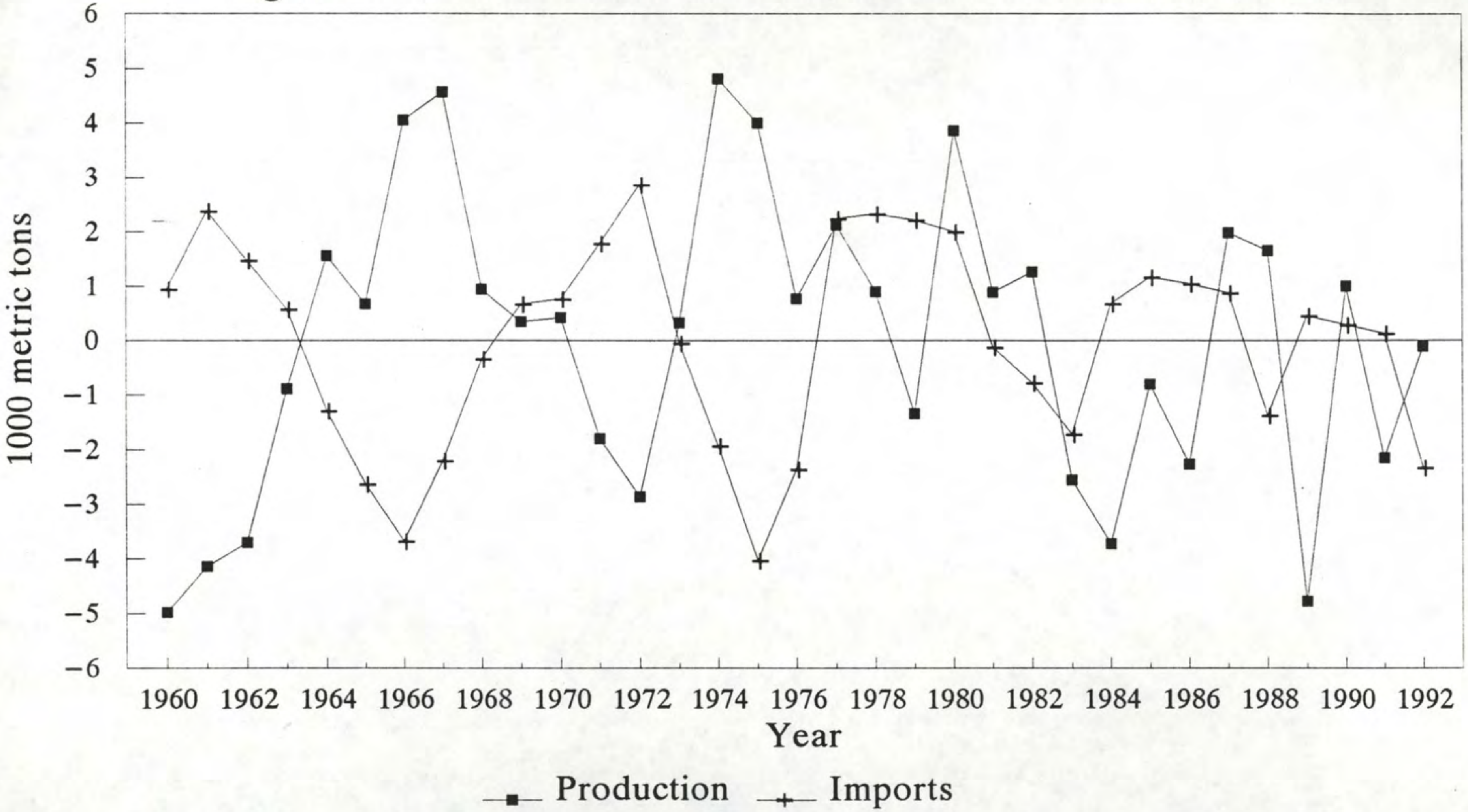
Randomness in commodity supply, for example severe drought, can not only inflict perilous distress on farmers, but also cause loss of human lives and decimate a country's economy as experienced by Ethiopia and Sudan in the mid 1980s. Thus the stochastic nature of production can determine the well being of a country, particularly if the country heavily depends on agriculture for its economic prosperity as most of the developing countries do. Also, ample evidence suggests that a considerable amount of agricultural trade is determined by temporary aberrations in supply. For instance, Blandford and Schwartz (1983) found that the bulk of the variability in wheat trade is generated by the transmission of fluctuations in the domestic production of the developing countries. More specifically, they found that production fluctuations were the principal determinant of annual deviations from trend exports in four out of five major wheat exporters. Their results also indicated that fluctuations in domestic production significantly influenced the volume of imports. Blandford

(1983) also reached similar conclusions. Thus, a positive (negative) relationship between production and exports (imports) arises from stochastic supply.

Furthermore, A shortfall in domestic production can make an exporting country become an importing country. Similarly, a bumper crop can switch a country from importer to exporter status. A classic example is Indian wheat trade. Between 1970 and 1991, India imported wheat in 12 years and exported in 10 years. Also evident from the plot of deviations from trend production and imports in figure 1 is that India imported wheat in the years of production shortages and exported in the surplus years.

Since 1970 the volume of world wheat trade has increased substantially. Wheat trade rose from 55 million tons (18% of world production) in 1970/71 to 121 million tons (22% of world production) in 1990/91. Since a significant portion of production is sold in the world market, production fluctuations are bound to influence the world market. India is one of the largest wheat producing countries, next to China, the European Community, the Former Soviet Union, and the United States. For instance, in 1990/91 India produced 10% of the world wheat production. Indian wheat production increased from 10.3 million metric tons in 1960 to 55.1 million metric tons in 1991. However, as Hazell (1982) noted, this remarkable increase in production is also accompanied by increased production instability. Since two-thirds of production was consumed by family farms, even modest variations in production can cause significant price fluctuations (Hazell, 1982). Given the large volume of production and lack of adequate storage facilities, fluctuations in Indian wheat supply are likely to have significant impacts on the world wheat market.

Figure 1. Trend Deviations of India's Production and Trade



The purpose of this study is to (i) analyse the effects of stochastic wheat supply in India on domestic and world price variability, trade flows of India and major exporters and importers, and India's balance of trade in wheat and (ii) explore the need for structural and policy adjustments in storage programs and domestic and trade policies of the Indian wheat market. A stochastic simulation analysis is employed to tackle the empirical analysis. Section II presents the theoretical model by describing the effect of production instability on price variability, trade flows, and balance of trade. Section III provides the methodology used in the simulation analysis. Section IV describes the structure of the empirical model, data, and the exporting and importing regions included in the study. Section V presents the empirical analysis and the results. The final section provides the concluding remarks and policy implications.

II. Theoretical Model

In this section, following Bigman (1982), we use a stylized model to examine the impact of Indian wheat production instability. Consider a closed economy model with linear supply and demand functions for India's wheat market

$$S = a + b\, P_t + u_t \qquad (1)$$

$$D = c - d\, P_t \qquad (2)$$

where S is supply; D is demand; P is price; a, b, c, and d are positive coefficients; and u is stochastic supply disturbances. The stochastic term is assumed to be distributed with mean zero and variance σ^2. We assume that consumers' tastes and preferences are stable and demand is not subject to random fluctuations.

The autarky equilibrium price is solved by equating domestic demand and supply:

$$P_t = \frac{c-a-u_t}{b+d}. \tag{3}$$

The mean and variance of the autarky equilibrium price are, respectively,

$$\bar{P}_t = \frac{c-a}{b+d} \tag{4}$$

$$V(P_t) = \frac{\sigma^2}{(b+d)^2}. \tag{5}$$

Next, the autarky model is expanded to allow for wheat trade, say, among n countries. The domestic supply and demand functions for these countries are

$$S_i = a_i + b_i P_{it} + u_{it} \tag{6}$$

$$D_i = c_i - d_i P_{it}, \tag{7}$$

where, i = 1, ..., n, and other variables are defined as before. The stochastic disturbance vector $[u_1, u_2 ..., u_n]$ is distributed with mean $[\mu_1, \mu_2 ... \mu_n]$ and variance $[\sigma_1^2, \sigma_2^2, ... \sigma_n^2]$. All covariance terms are assumed zero, implying that supply shifts in different countries are governed by independent forces. The linearity and additive risk assumptions simplify determination of market equilibrium in a multicountry world, because they generate linear excess demand/supply equations. Throughout the analysis country 1 is assumed to be India.

Excess supply/demand for country i is given by

$$X_i = S_i - D_i = a_i + b_i P_{it} + u_{it} - c_i + d_i P_{it}. \tag{8}$$

Country i is an exporting (importing) country if X_i is positive (negative). World equilibrium requires that

$$\sum_{i=1}^{n} X_i = 0. \tag{9}$$

Equilibrium world price P_w is determined from (9) by setting all $P_{it} = P_{wt}$:

$$P_{wt} = \frac{\sum_{i=1}^{n} (c_i - a_i - u_i)}{\sum_{i=1}^{n} (b_i + d_i)}. \tag{10}$$

The mean and variance of the equilibrium world price are, respectively,

$$\bar{P}_{wt} = \frac{\sum_{i=1}^{n} (c_i - a_i)}{\sum_{i=1}^{n} (b_i + d_i)} \tag{11}$$

$$V(P_w) = \frac{\sum_{i=1}^{n} \sigma_i^2}{\left[\sum_{i=1}^{n} (b_i + d_i)\right]^2}. \tag{12}$$

It should be emphasized that the variance of world price given in (12) is under the assumption that all the countries experience stochastic supply fluctuations. Suppose, only India experiences fluctuations in supply, i.e., $u_2 = \ldots = u_n = 0$. The equilibrium world price and variability under this scenario is

$$P_{wt} = \frac{\sum_{i=1}^{n} (c_i - a_i) - u_1}{\sum_{i=1}^{n} (b_i + d_i)} \tag{13}$$

$$V(P_w) = \frac{\sigma_1^2}{\left[\sum_{i-1}^{n} (b_i + d_i)\right]^2} . \tag{14}$$

Comparing the price variability under autarky condition, equation (5), and under trade, equation (14), it is clear the degree of price variability in India is reduced as a result of trade. Thus, trade acts as a buffer program that helps to stabilise prices.

The effect of stochastic supply on trade volume of other countries can be determined by computing the difference in the level of trade under random and nonrandom supply shocks. Thus, export or import volume changes for country i is:

$$X_i = (a_i + b_i P_{wt} - c_i + d_i P_{wt}) - (a_i + b_i \bar{P}_{wt} - c_i + d_i \bar{P}_{wt})$$

$$= -(b_i + d_i) \frac{u_1}{\sum_{i=1}^{n} (b_i + d_i)} . \tag{15}$$

where P_{wt} is the world price resulting from stochastic supply in India, equation (13), and $\bar{P}_{wt}$ is the world price under nonrandom supply, equation (11). The results in (15) indicates that the effect of random supply fluctuation on country i's exports or imports depends on domestic supply and demand elasticities (i.e., coefficients b_i and d_i) and the changes in the world price captured by the term $\frac{-u_1}{\sum_{i-1}^{n} (b_i + d_i)}$.

Next, India's balance of trade in wheat is shown to depend on the price variability and supply and demand elasticities. India's balance of trade in wheat can be written as

$$BT = P_{wt}\,[S\,(P_{wt}) - D\,(P_{wt})], \tag{16}$$

where the BT is the balance of trade (or equivalently, export revenue if BT > 0 and import cost if BT < 0) and P_{wt} is world price from equation (13). The expected balance of trade, under the linear supply and demand is,

$$E(BT) = a_1\,E\,(P_{wt}) - c_1\,E\,(P_{wt}) + (b_1 + d_1)\,E\,(P_{wt})^2 + E\,(P_{wt}\,u_{1t}). \tag{17}$$

By substituting the appropriate expression for $E(P_{wt})^2$ and $E(P_{wt}u_{1t})$, we can show that

$$E(BT) = E\,(P_{wt})\,\{a_1 + b_1\,E\,(P_{wt}) - [c_1 - d_1\,E\,(P_{wt})]\} + \frac{\sum_{i=2}^{n} (b_i + d_i)\,(b_1 + d_1)}{\left[\sum_{i=1}^{n} (b_i + d_i)\right]^2}\,(b_1 + d_1)\,V(P_1). \tag{18}$$

Since India is a wheat exporter in some years and importer in other years and self-sufficient on average, the expected level of exports is assumed to be zero, and thus, the first term in the above equation drops out. Therefore, expected balance of trade

$$E\,(BT) = \frac{\sum_{i=2}^{n} (b_i + d_i)(b_1 + d_1)}{\left[\sum_{i=1}^{n} (b_i + d_i)\right]^2}\,(b_1 + d_1)\,V(P_1) \tag{19}$$

depends on the price (or supply) variability in India and demand and supply elasticities in India and other countries.[1]

III. Methodology

A stochastic simulation procedure is used to analyse the impacts of Indian wheat instability in this study. The stochastic simulation procedure is based on the large sample theory that the distribution of a sample approaches that of the true population as the sample size increases. Stochastic simulation is used to analyse the behavior of the endogenous variables in response to random shocks. For example, production fluctuations are due to random shocks generated by weather vagaries, pests, and disease. These production fluctuations cause inherent instability in the market, and the stochastic simulation approach is an appropriate technique to study the effects of these instabilities on other endogenous variables. McCarthy (1982) has provided the methodology for undertaking stochastic simulations, which is briefly discussed next.

Consider the following definition of pseudo-structural disturbances:

$$V = \frac{1}{\sqrt{T}} rU \tag{20}$$

where V is a 1 x M matrix of pseudo-structural disturbance; r is a 1 x T vector of random numbers, normally distributed with zero means and unit variances; U is any T x M matrix of disturbances from T observations of M true structural equations, and has M x M covariance matrix $\Sigma = T^{-1}EU'U$. Since r is standard normal, and is independent of U, the covariance matrix of V is given by

$$\Sigma_V = EV'V = \frac{1}{T} EU'r'rU = \frac{1}{T} [EU'U]I = \Sigma. \tag{21}$$

Substitution of estimated sample residuals, $\hat{U}$, for U yields the disturbance vector and its covariance matrix:

$$\hat{V} = \frac{1}{\sqrt{T}} r\hat{U} \tag{22}$$

$$\hat{\Sigma}_V = \frac{1}{T} E\hat{U}'\hat{U} = \hat{\Sigma}. \tag{23}$$

In empirical application, however, $\hat{\Sigma}$ is estimated first, and $\hat{V}$ is computed using r as follows (see, Chowdhury and Heady, 1980). Define

$$\hat{V} = Hr, \tag{24}$$

such that

$$E(Hrr'H) = HE(rr')H' = HH' = \hat{\Sigma}. \tag{25}$$

Since Σ is a symmetric positive definite matrix, Cholesky decomposition can be applied to obtain a unique lower triangular matrix H. From equations (21) and (25), it is clear that V in (24) is equal to that in (20).

The stochastic component of the model is production.[2] Since we are examining the effects of random production in India only, V is a 1x1 scalar, and Σ is also scalar, i.e., it is the variance of the disturbance term.

Next, we explain how $\hat{V}$ is computed in this study. A trend equation for production is estimated using

$$S = \alpha T + U \tag{26}$$

where S is the wheat production in India; T is time trend (T=1 in 1970 and 21 in 1990); alpha is the coefficient, and U is the stochastic disturbance. The estimated residuals is

$$\hat{U} = S - \hat{\alpha}\, T. \tag{27}$$

The estimated variance of the residuals is denoted as $\hat{\sigma}^2$. The computed residual is

$$\hat{V} = r\hat{\sigma}. \tag{28}$$

Once $\hat{V}$ is computed, it is substituted into the trend production equation to generate the random production:

$$\hat{S} = \hat{\alpha}\, T + \hat{V} \tag{29}$$

By repeating this process, twenty random production values are generated for the year 1990. Table 1 presents the simulated values, mean, and variance of production computed from the twenty simulated values. The mean production of twenty simulated values is 50.7 million metric tons, which is close to the actual production of 49.9 million metric tons in 1990. The standard deviation of the simulated production is 15.3 million metric tons. Of the twenty stochastic simulations scenarios, production shortfalls (surpluses) occurred in thirteen (seven) scenarios, i.e., the simulated productions are below (above) the actual production. Production values generated from each simulation are incorporated in the spatial equilibrium model, which is run twenty times to generate the values of other endogenous variables.

IV. Empirical Model

In this section, the spatial equilibrium wheat model used for analysing the impacts of randomness in Indian Wheat Production is described. The model assumes the world wheat market is divided into spatially separate exporting and importing regions. Table 2 lists the 11 exporting regions and 23 importing regions included in the model. This trade modeling approach is best suited to ascertain the impacts of exogenous shocks on prices and trade flows between countries. Consider the following simple quantity dependent excess demand and supply functions, respectively,

$$Q_j = a_j - b_j P_j$$

$$Q_i = c_i + d_i P_i,$$

where a, b, c, and d are parameters,

$Q_j = \sum_{i=1}^{11} X_{ij}$ = sum of shipments to importing country j from 11 exporting countries, $(j = 1, \ldots, 23)$,

Table 1. Indian Wheat Production Generated from Twenty Stochastic Simulations

	Simulation Runs	Production million metric tons
	1	48.9
	2	48.3
	3	37.5
	4	36.4
	5	49.9
	6	68.2
	7	46.6
	8	49.6
	9	41.6
	10	67.1
	11	65.6
	12	79.2
	13	49.5
	14	12.3
	15	59.6
	16	36.3
	17	38.4
	18	64.9
	19	48.8
	20	65.8
Mean		50.7
Standard Deviation		15.3
Actual Production in 1990		49.9

Table 2. Exporting and Importing Regions Included in the Spatial Equilibrium World Wheat Model.

Exporting Regions	Importing Regions	
Canada	China	Egypt
Eastern Ports	Former Soviet Union	Brazil
Western Ports	Japan	Mexico
United States	East Asia	Other South America
Columbia River	South East Asia	Venezuela
Puget Sound	Indonesia	Nigeria
Gulf	Thailand	North Africa
Atlantic	South Asia	West Central Africa
California	**India**	East Africa
Great Lakes	Middle East	South Africa
	Eastern Europe	Central America and Caribbean
European Community	Other Western Europe	
Australia		
Argentina		

$Q_i = \sum_{j=1}^{23} X_{ij}$ = sum of shipments from exporting country i to 23 importing countries, (i = 1, ..., 11), and

P_j and P_i are prices at the importers' and exporters' ports, respectively. The excess demand and supply functions are written in the price dependant form as

$$P_j = \frac{a_j}{b_j} - \frac{1}{b_j}Q_j$$

$$P_i = -\frac{c_i}{d_i} + \frac{1}{d_i}Q_i$$

With the above excess demand and supply functions, the specifications of spatial equilibrium are given as:

Maximize

$$Z = \sum_{j=1}^{23} \left[\int_0^{Q_j}\left(\frac{a_j}{b_j} - \frac{1}{b_j}Q_j\right)dQ_j\right] - \sum_{i=1}^{11} \left[\int_0^{Q_i}\left(-\frac{c_i}{d_i} + \frac{1}{d_i}Q_i\right)dQ_i\right] - \sum_i^{11}\sum_j^{23} T_{ij}X_{ij}$$

$$= \sum_{j=1}^{23}\left(\frac{a_j}{b_j}Q_j - \frac{1}{2}\,\frac{1}{b_j}Q_j^2\right) - \sum_{i=1}^{11}\left(-\frac{c_i}{d_i}Q_j + \frac{1}{2}\frac{1}{d_i}Q_i^2\right) - \sum_i^{11}\sum_j^{23} T_{ij}X_{ij}$$

subject to

(1) $Q_j = \sum_{i=1}^{11} X_{ij}$, j = 1, .., 23

(2) $Q_i = \sum_{j=1}^{23} X_{ij}$, i = 1, .., 11

(3) $P_j \geq 0$, j = 1, .., 23

(4) $P_i \geq 0$, i = 1, .., 11

(5) $X_{ij} \geq 0$, i = 1, .., 11, j = 1, .., 23

(6) $P_j - P_i \leq T_{ij}$ i = 1, .., 11, j = 1, .., 23

where T_{ij} = transportation costs per unit from export ports to import ports, and

Z = net social benefit.

Constraints (1) and (2) ensure that the import demand of each importer is met by the exporters. Constraints (3) and (4) guarantee that export and import prices are nonnegative. Constraint (5) entails that trade flow from region i to j is nonnegative. Constraint (6) ensures that trade between regions i and j will not occur if the price differential between these regions is less than the ocean shipping cost. Policy variables and transportation costs enter the model as exogenous variables. Prices and trade flows are the solution variables.

Except for Canada and the United States, the excess demand and supply parameters are derived using the elasticity parameters and the average values of quantities and prices over the three year period 1987-1989. The excess demand and supply elasticities were obtained from the USDA (1986). Since the elasticities for the individual ports in the United States and Canada were not available, the parameters of the excess supply functions for these regions were estimated using regression. The details on parameter computation, regression results, and the data are available from the authors upon request. The quadratic programming formulation in the GAMS (General Algebraic Modelling System) computer package is used to solve the model. Additional details about the model can be found in Li (1993).

V. Empirical Analysis

The random productions generated in equation (29) along with the actual consumption in 1990 are used to compute the coefficients of excess demand/supply of India. These coefficients are incorporated into the model, and the model is solved to obtain prices and trade flows. This process is repeated twenty times using the twenty random productions. In the interest of brevity, instead of presenting the results corresponding to twenty simulations, only comparisons of mean and actual values, and variabilities in key endogenous variables are presented in table 3.

We computed the effects of Indian production instability on price variability under autarky and trade conditions. Variability is measured using standard deviation. Since India does not have adequate storage facilities, the instability in production increases domestic price variability. Under the autarky condition, the production instability of 15.3 million metric tons causes the domestic price variability of $71 per metric ton. The mean price in India under the autarky case is $169.1 per metric ton, which is significantly higher than the actual price of $141.1 under the existing trade patterns.

The production shortfalls in thirteen scenarios forced India to import, and the surpluses in seven scenarios caused India to export.[3] The mean value of imports is 0.2 million metric tons and of exports is 12.5 million metric tons. This export volume is more than 25% of actual production in 1990. In 1990, India was a net exporter, but its actual net exports were only 0.1 million metric tons. It is interesting to note that import prices are higher than export prices because India pays for the transportation costs on its imports. An interesting point to note is that once trade is allowed, the price variability reduces significantly from $71 per metric ton to $21 per metric ton (not shown in table 3). Thus, trade helps to stabilise the price variability. Stated differently, free trade acts as a buffer stock program in stabilising the price variability. These results corroborate similar findings by Johnson (1975).

The simulated mean price in India under the trade scenario is $153.3 per metric ton (not shown in table 3), which is comparable to the actual price of $141.1 in 1990.

Table 3. Simulation Results of Indian Wheat Production Instability.

	Price			Trade Flows		
	Actual in 1990	Mean of Simulated Values	S.D. of Simulated Values	Actual in 1990	Mean of Simulated Values	S.D. of Simulated Values
	-------$ Per Metric Ton------			---------1000 Metric Tons---------		
India						
Under Autarky	NA	169.1	71.0	NA	NA	NA
Under Trade						
Imports	141.1	157.8	0.2	147.0	157.5	142.3
Exports	141.1	126.3	9.4	305.0	12498.2	4607.9
Exporters						
Canada						
East	137.0	136.2	10.2	6782.0	7989.6	304.0
West	147.0	133.0	14.0	10427.0	6156.3	376.7
United States						
Columbia River	123.7	132.8	14.0	11115.0	9730.3	423.3
Puget Sound	123.7	133.0	14.0	148.0	296.8	79.8
Gulf	118.3	130.4	10.2	15279.0	18174.8	952.5
Atlantic	108.0	134.7	10.2	709.0	1448.8	49.8
California	123.7	132.2	13.4	897.0	628.0	85.8
Great Lakes	108.0	132.1	10.2	1607.0	2309.9	160.6
European Community	90.0	138.2	10.2	33565.0	28926.2	309.0
Australia	127.0	134.5	14.0	12100.0	12754.1	197.6
Argentina	87.0	133.7	12.7	5300.0	4200.3	58.4

Table 3. Simulation Results of Indian Wheat Production Instability (Contd.).

	Price			Trade Flows		
	Actual in 1990	Mean of Simulated Values	S.D. of Simulated Values	Actual in 1990	Mean of Simulated Values	S.D. of Simulated Values
	-------$ Per Metric Ton------			---------1000 Metric Tons---------		
<u>Importers</u>						
Other West. Europe	200.6	150.7	10.2	548.0	811.4	26.8
Eastern Europe	148.7	150.9	10.8	1477.0	2397.5	156.4
Middle East	153.0	152.2	10.2	13919.0	16898.5	812.9
China	173.3	154.0	14.0	13487.0	14379.6	863.3
Japan	186.1	147.8	14.0	5474.0	5631.1	17.0
East Asia	168.3	151.0	14.4	3195.0	4277.2	157.1
South East Asia	171.7	153.1	14.0	2976.0	4394.5	101.9
South Asia	175.7	158.5	14.0	4605.0	3685.5	264.7
Indonesia	163.2	153.1	14.0	1767.0	1724.6	42.5
Thailand	181.8	157.2	13.9	374.0	299.0	6.1
Former Soviet Union	165.9	151.0	10.2	15275.0	15337.1	815.0
Egypt	179.8	152.2	10.2	6615.0	7472.0	60.7
Brazil	95.2	146.2	12.7	2218.0	1660.6	13.6
Mexico	149.6	135.6	10.2	358.0	674.5	57.3
Cen. Ameri. & Caribbean	150.1	142.9	10.2	2475.0	2695.6	20.6
Other South America	166.8	142.9	10.1	2261.0	2387.0	50.4
Venezuela	170.6	142.9	10.2	992.0	1076.4	25.7
Nigeria	210.5	156.0	12.7	252.0	63.8	0.2
North Africa	163.1	151.2	10.2	7215.0	7313.6	199.6
West Central Africa	208.7	156.0	12.7	1535.0	1486.7	28.1
East Africa	186.3	162.2	12.9	1554.0	1759.4	30.4
South Africa	166.1	153.6	12.7	1130.0	496.4	10.5

Comparison of the small volume of actual net exports to the simulated volume of exports indicates that production instability in India can have significant effects on the world wheat market. This result occurs because the smaller the domestic stocks relative to consumption, the larger the influence of domestic supply fluctuations on volume of trade. Consequently, the lack of storage facilities causes Indian production instability to spill over to the world market through its imports and exports. This is reflected in the world price variability of $14.0 per metric tons. The world price variability is less than the price variability in India because of the following two factors. First, shocks caused by Indian production and trade instability are absorbed by the exporters and importers in the world wheat market, and thus, trade helps to stabilise the world price fluctuations. Second, because of Indian trade policies, world prices are not freely transmitted to the Indian wheat market. For example, Devadoss and Meyers (1990) note a price transmission elasticity of 0.51 which indicates that the domestic wheat price in India does not move freely with the world price.

Next, we examine the impacts on price variability and trade volume of other countries.[4] Since in the simulated scenario India's average exports are significantly higher than its imports, we would expect that exports by exporters would generally be lower and imports by importers would be higher. Canada's ports are designated as : East and West. In the western ports, the simulated mean volume of exports is significantly less than the actual volume of exports. Canada does experience price variability, but not as much as the world price variability. This result may occur because the Canadian export supply function reflects the fact that the Canadian Wheat Board has control over trade, and it can effectively reduce the transmission of world price variability to the Canadian wheat market.

The United States has six port regions, namely, the Columbia River, Puget Sound, the

Gulf, the Atlantic, California, and the Great Lakes. Of the six port regions, the Gulf port region is the largest for wheat exports with 15.3 million metric tons in 1990 followed by Columbia River ports with 11.1 million metric tons. The price variability in these six port regions ranges from $10.2 to $14.0 per metric ton. Simulated mean volume of exports from Columbia River ports is less than the actual exports. However, simulated mean volume of exports from Gulf ports is higher than the larger than the actual exports. The increase in Gulf port exports is attributed to the proximity, and thus, lower transport cost.

The mean volume of exports of the European Community and Argentina is less than the actual exports, but Australia's exports slightly increased in the simulation analysis. Of these three countries, Australia has the highest price variability, which indicates that Australia follows relatively freer trade policies in wheat trade.

There are 23 importing regions, including India. China, the former Soviet Union, and the Middle East are the largest importers. As one would expect the simulated mean volume of imports of most of the importers is larger than the actual volume of imports. The price variability ranges from $10.1 per metric ton in the other South American region to $14.4 per metric ton in East Asia. The high price variability in China, South East Asia, East Asia, and Indonesia may reflect the lack of adequate storage facilities, and these countries are not able to offset the effects of wide swings in the world wheat market. The lower variabilities of import volumes by countries such as Japan indicate government control trade schemes which insulate the domestic market from world market fluctuations.

VI. Summary and Implications.

Indian wheat production is highly unstable because of adverse weather factors, which can cause catastrophic effects. Fluctuations in wheat production and ensuing price variability are heavily borne by the poor and may have adverse effects on farm incomes (Hazell, 1982). Furthermore, since India is one of the largest producers of wheat, instability in its wheat production can have significant effects on the world wheat market. The objective of this study is to analyse the effects of stochastic wheat supply in India on domestic and world price variability, and trade flows of India and major exporters and importers. These goals are achieved by conducting stochastic simulation analysis. More specifically, twenty stochastic simulation runs were carried out for the year 1990, and the impacts were analysed by comparing the mean values of the simulations and the actual values in 1990, and standard deviation of the simulations for key endogenous variables.

Some key results are as follows: under autarky conditions, the production instability causes price variability of $71 per metric ton. One of the reasons that India is not able to contain the transmission of the production instability to high price variability is because of the lack of adequate storage facilities. Consequently, wide swings in production are reflected by the price fluctuations. Once trade is allowed, the price variability in India is reduced. Production instability in India increases the variability of exports, imports and prices of other countries. For instance, the variability of U.S. export price and the volume of exports (average of six ports in the United States) increase by $12.0 per metric ton and 5 million metric tons.

Results in this study confirm that wheat production instability in India is significant enough to inflict variability in the world market; therefore, India can not be excluded in international efforts to reduce market instability. As in most cases, the production instability in India is undesirable. Some implications of instability are discussed next. First, production shortfalls would raise the world wheat price; though it may benefit exporters, most poor importing countries have to pay more for their imports. On the other hand, production surpluses in India would lower world prices, and thus, benefit importers and hurt exporters. The wheat production instability in India may pose serious problems to its economy.

Second, India has a long and persistent problem with its foreign exchange position. Wheat production shortfalls arising from adverse weather patterns for two or three years in a row can cause a serious shortage of wheat and force India to import wheat. Under these circumstances, the persistent deficits in India's foreign exchange position can force India to sacrifice its other vital imports to conserve foreign expenditures and to expand its traditional exports to increase foreign earnings, so that it can pay for its wheat imports. Such trade adjustments will worsen its terms of trade and adversely affect its economy. Of course, production surpluses would improve its terms of trade, foreign exchange positions, and the economy.

Third, production shortfalls and ensuing price increases also affect the demand and supply for substitute food products. For example, wheat and rice are strong substitutes in India. Shortage of wheat would force India to import rice, and thus exacerbate its deteriorating terms of trade. Furthermore, instability in wheat supply can destabilise substitute and complement product markets.

Fourth, the instability can also affect the future wheat supply, particularly if farmers are risk-averse. Risk-averse farmers would tend to allocate less of their resources to wheat supply and more to other crops. This is particularly true in India because wheat is grown as a rainfed crop and is highly susceptible to weather vagaries. A trend towards allocating less and less acreage in wheat can cause serious perils to Indian food security.

The chief conclusions of this study are that wheat production instability is an inevitable consequence of factors such as weather, pests, and disease, and other natural and man-made catastrophes. The policy makers need to formulate domestic food policies, trade policies, storage schemes, and stabilization programs such that the effects of production instability can be offset and the nation's food security can be safeguarded. In particular, Indian government and the agricultural industry need to increase and improve grain storage facilities to avoid critical shortage of food arising from the ravages of drought. Although accumulation and proper management of stocks may not totally eliminate the market volatility, they will significantly reduce economic stress posed by the wide swings in supply. Also, improved storage facilities will reduce the transmission of domestic price variability to importers and exporters. The simulation analysis of domestic supply disturbances under autarky and trade conditions demonstrate how India can buffer price variations through trade.

Endnotes

1. If supply is random in other countries, then E(BT) would also depend on the price variability in other countries.

2. Production would capture the stochastic elements better than yield because stochastic elements in production contain variability in both the yield and acreage.

3. Since trade is determined for a given level of consumption in 1990, twenty random productions lead to imports in thirteen scenarios and exports in seven scenarios. If consumption were subject to random shocks, one would expect imports and exports to occur approximately in equal number of times.

4. Even though, net trade results are presented, results on trade flows between any two countries are available from the authors upon request.

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