WORLD GRAINS: EVALUATING THE USE OF BUFFER STOCKS FOR REDUCING THE IMPACT OF YIELD VARIABILITY OF FOUR GRAINS

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Introduction

The issue of buffer stocks has been debated by various world agencies, and has stimulated contributions on the theoretical and empirical benefits of buffer stock schemes. The aim of this paper is to contribute to the current debate by describing the welfare results of simulating world production and consumption of four grains over a 20 year period before and after the introduction of alternative buffer stock schemes. Results from various models of this type have already been published (for example, see Cochrane and Danin; Johnson; Kennedy; Reutlinger; Sharples, Walker, and Slaughter; and Zwart and Meilke). The purpose of developing another model is to complement such results by taking a more disaggregated approach.

The world is divided into three regions: North and Central America (NCA); USSR, Europe, and Oceania (UEO); and China, Asia, Africa, and South America (CAAS). Income levels and consumer preferences may be assumed to be similar within the NCA and UEO regions. The CAAS region, representing the developing world, contains a much more heterogeneous set of countries, which could be subgrouped further in a more refined model.

The four grains selected are wheat, rice, maize, and barley. Wheat and rice represent the staple grains for human consumption, and maize and barley are taken as representative of the coarse grains mainly used for livestock feeding.

Model Description

For simplicity, a stationary process is assumed. Variables simulated in each year of a 20 year run do not take account of any trend changes, but relate to the 1975 base year. Production and trade relationships were estimated using FAO data where available for the years 1955 to 1975.

The simulation components of the model deal with production, consumption, and price determination. A decision component models storage, and an evaluation component records the impact of storage decisions on price variability, social economic benefits, and variability in the availability of energy intake from grains. These components are described in turn. Their interaction is summarized in equations (1) to (17) in figure 1. The following subscript notation is used: i = 1, 2, 3 refers to a particular region, whilst j = 1, 2, 3, 4 refers to a particular grain.

Production [Equations (1) and (2)]

Production (G) equals planted area (L) (which is assumed to be fixed) times yield (Y). Y equals the linear trend yield for 1975 $(\overline{Y})$ plus an error term (E). E is a random variable drawn from multivariate normal distributions of deviations from trend for each grain within the j-th region. Thus, it is assumed that all yields are approximately normally distributed, that the E are independent through time, and that there are no yield correlations between regions. The Kolmogorov-Smirnov test and the Durbin-Watson statistics show that the first two assumptions to be reasonable with few exceptions. About 30 percent of within region yields are significantly positively correlated. As regards between region correlations, about 10 percent are significantly negative and about 10 percent significantly positive.

Yield Production

$$Y_{ij} = \overline{Y}_{ij} + E_{ij} \quad (1)$$

$$G_{ij} = L_{ij} \cdot Y_{ij} \quad (2)$$

Storage

$$\Delta S_{ij} = S\{S_{ij}, G_{ij}, LB_{ij}, UB_{ij}, CL_{ij}\} \quad (3)$$

Availability

$$A_{ij} = G_{ij} - \Delta S_{ij} \quad (4); \qquad A_j = \sum_i A_{ij} \quad (5)$$

Consumption

$$C'_{ij} = d_{ijo} + \sum_{k=1}^{4} d_{ijk} \cdot A_k + d_{ij5} \cdot POP_i + D_{ij} \quad (6)$$

$$C_{ij} = C'_{ij}(A_j / \sum_i C'_{ij}) \quad (7); \qquad C = \sum_i \sum_j C_{ij} \quad (8)$$

Exports

$$X_{ij} = A_{ij} - C_{ij} \quad (9)$$

Price

$$P = P\{C\} \quad (10)$$

Consumer Surplus

$$CS_{ij} = (\int_0^C P\{Q\}\, dQ - C.P\{C\}).(C_{ij}/C) \quad (11)$$

Producer Revenue

$$PR_{ij} = P.G_{ij} \quad (12)$$

Intervention Costs

$$IC_{ij} = P.\Delta S_{ij} \quad (13)$$

Storage Costs

$$SC_{ij} = k.S_{ij} \quad (14)$$

Social Benefit

$$SB_{ij} = \Delta CS_{ij} + \Delta PR_{ij} - IC_{ij} - \Delta SC_{ij} \quad (15)$$

Export Revenue

$$ER_{ij} = X_{ij}.P \quad (16)$$

Calorie Availability

$$CA_i = \sum_j C_{ij}.W.(1-ML_j)/(POP_i.365) \quad (17)$$

Figure 1. Flow diagram for the simulation of one year.

Consumption [Equations (4) to (9)]

Rather than attempting to simulate trade directly with a supply and demand model, simple linear regression equations for regional consumption are used. Regional consumption of each grain was regressed on world production of all grains and regional population (POP). Regional consumption (C) of each grain estimated from these equations is standardized by multiplying by the ratio of simulated world availability of the grain to estimated world consumption of the grain. This ensures that global exports equal global imports.

The random error term (D) permits variability in the estimates of regional consumption. D is drawn from regional multivariate normal distributions, based on the means and variance-covariance matrices of historical error terms of standardized consumption.

Exports (X) are defined as grain available within a region after any storage (A) less consumption (C).

Price [Equation (10)]

The system for simulating consumption did not permit the simultaneous determination of the regional price for each grain. In the absence of regional own and cross price functions for each grain, a global price indicator (P) is used. Global price is a function of total world consumption of all four grains (C). Such a global price is a very approximate device because its use implies perfect demand substitutability between grains and ignores price differentials which result from trade barriers and transport costs.

The total demand for world production of grains can be expected to be very inelastic in the short run. A constant price elasticity of demand of -0.1 was used in most runs of the model. Price was set equal to U.S.$120 per metric tonne for consumption equal to mean consumption.

Storage Rules [Equation (3)]

The efficacy of storage rules set in terms of production, prices, stocks, or emergency situations has been much debated. To be politically acceptable, storage rules have to be seen as fair and not offering scope for windfall gains. In the model, regional storage is a function of regional production relative to planned production. With the increasing accuracy of estimates of production from satellite observations, such a storage system would be practical. Production determined storage rules are not divorced from market signals to the extent that area planted to grain is responsive to price.

Lower and upper production bounds (LB and UB) are set around the mean production for triggering release and accumulation of stocks so that consumption falls within these bounds to the degree that stock levels (S) and storage capacity limits (CL) permit. For most runs of the model, regional storage capacity limits for each grain were set equal to 20 percent of the mean production.

Opening regional stock levels for wheat, rice, maize, and barley were set to equal 12, 4, 8, and 8 percent of mean regional production respectively. These are historically low levels and therefore represent feasible takeoff levels in practice.

Storage costs (before interest charges but including fixed costs) are $10 per tonne per year. A high value was chosen to cover costs of deterioration of stored grains.

Storage rules can be specified for any combination of region and grain. Further, integrated world storage policies based on trigger levels for world production are allowed. Storage activity and associated costs are shared between regions in proportion to mean regional production. A world storage policy allows greater flexibility because regional storage is no longer restricted by regional stock levels. However, for all policies, world and regional, any opportunities for storing different grains at different times in the same storage facility are ignored.

Evaluation of the Effects of Storage [Equations (11) to (17)]

The model keeps track of welfare variables in each of the simulated years if an active storage policy is followed, compared with what they would have been if stocks had been maintained throughout the 20 year period at their opening values. The social benefit of a storage scheme is defined as the present value of the stream of annual social benefits (see figure 1) in each period t:

$$SB_{ijt} = \Delta CS_{ijt} + \Delta PR_{ijt} - IC_{ijt} - \Delta SC_{ijt}$$

A real rate of interest of 3 percent per year is used for discounting.

If a region pursues a storage policy, costs or benefits follow for consumers and producers in all regions. However, intervention and storage costs are specific to the region. Intervention costs include the discounted value of the difference in the closing levels in year 20 and the opening stock in year 1.

Results for Selected Storage Policies

For each policy, 100 replications of a 20 year period were run. Storage trigger levels were set at 0.1 standard deviations above and below the mean production.

An active policy implemented only for wheat by the NCA region results in an increase in social benefit for each region ($690 million in total). However, the probability of per capita energy intake falling below 1,750 calories per day remains at 23 percent for the CAAS region, the region most at risk. Milling losses (ML) for wheat, rice, maize, and barley are assumed to be 10, 30, 10, and 10 percent respectively. Energy content (W) is taken to be 3,500 calories per kilogram of milled grain. By contrast, an active policy followed only for rice by the CAAS region leads to a substantial reduction in the probability of such a shortfall--to 12 percent. Changes in social benefit for the NCA, UEO, and CAAS regions are -$6,600, +$100 and -$12,000 million respectively. In all regions under both policies, consumers gain and producers lose.

Because most discussion on storage policy centres on wheat, the implications of alternative combinations of regional policies for wheat were tested. The UEO region as both the major producer of world wheat (50 percent) and the major importer of all grains gains most from an increase in the number of regions following a policy for wheat. If all regions follow an independent storage policy for wheat, changes in social benefit for the NCA, UEO, and CAAS regions are -$2,600, +$5,600 and +$1,700 million respectively. A switch to a cooperative world policy for wheat under which storage facilities are shared increases world social benefit from $4,700 million to $5,400 million.

Conclusion

The UEO region stands to benefit from storage policies for wheat and barley, and the CAAS region from a policy for rice. The NCA region, being an exporting region, would lose. However, the loss would not be as great to the extent that rice does not substitute perfectly for wheat in consumption. Also, the scope for policies for rice may be curbed by technical difficulties in storage.

Storage policies could bring benefits without maintaining average stock levels much higher than the low levels of the 1972-74 period, with the exception of rice. An upper capacity limit of 20 percent of the mean production is desirable if price and consumption variability are seen as major problems, otherwise a lower capacity limit would be preferred so that storage costs are reduced and social benefit is increased.

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RAPPORTEUR'S REPORT--E. David Walker

The discussion generally centred on the applicability of the paper due to the limitations of the model and results. The regional division of the world was not considered particularly relevant with regard to actual stockpiling policy development. The author noted that the study could be replicated with different regional selections to provide more relevant guidance in this respect. The constant stock level and free trade assumptions were also believed to limit the validity of the results in a practical context.

The rural social benefits suggested by the study were relatively minor in comparison with the rural value of global grain production. Further, the relatively large social benefits for the CAAS region for rice in comparison with other regions and other grains was related to the scale of rice production in the CAAS region rather than to any fundamental difference in the impact of stock policy.

It was suggested that it would be appropriate for individual countries to utilize a game theory model in conjunction with this model when developing strategies with respect to buffer stock policies.

Contributing to the discussion were Hans G. Hirsch, Donald MacLaren, and Ammar Siamwalla.