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Is Commodity Storage an Option for Enhancing Food Security in Developing Countries?

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Is Commodity Storage an Option for Enhancing Food Security in Developing Countries?

by

G. Cornelis van Kooten

ABSTRACT

Traditional arguments for commodity storage assume that weather is a controllable input so that agricultural producers' total variable costs (and quasi-rents) are dependent on a shifting supply function. In this paper, an alternative explanation is offered that considers a fixed supply function but variable, weather-determined outputs. The standard result no longer holds unequivocally. With no government intervention, agricultural producers can fail to recoup their investment costs under good or bad weather outcomes, which incentivizes them to lobby for price stabilization policies. In developing countries, governments have a further incentive to store grain for food security – storage can prevent prices from rising so the most vulnerable can no longer afford to buy food. Numerical simulations indicate that extended periods of good or bad years can be troublesome because storage is no longer a neutral activity as there is a mismatch between purchases and sales.

Key words: Agricultural policy in developing countries; price stabilization and commodity storage; applied welfare economics.

JEL categories: Q02, Q18, Q11, Q13, O13

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1. INTRODUCTION

Agricultural policymakers have long sought to stabilize prices and incomes by relying on price controls and commodity storage when necessary. The economics of commodity storage has been a subject of economic research for nearly three-quarters of a century (see Waugh 1944; Oi 1961; Massell 1970; Samuelson 1972). The research generally finds that, in the case of stochastic supply, Waugh-Massell overestimates the gains to society from price stabilization. In the case of stochastic demand, the Oi-Massell approach finds that stabilization is Pareto optimal, but the Massell measure underestimates the actual gain to society (van Kooten and Schmitz 1985). If a buffer fund is employed rather than physical storage, there are no gains or losses to society: when there is demand instability, there are no gainer or losers, but, if there is supply instability, the producers gain at the expense of taxpayers (van Kooten et al. 1988). Society prefers a buffer stock to buffer fund, and producers favor the latter only if they are able to gain from rent seeking.

Recently, there has been increasing interest in commodity storage programs for reasons of food security, especially in developing countries (Meijerink and Joshi 2016; Schmitz and Kennedy 2016). However, as shown in this paper, the standard model used to analyze the economic efficiency and distributional effects of commodity storage programs is misleading because it assumes that weather is a variable input like any other. This results in a fallacious measure of quasi-rent. Although a factor in the production process, weather cannot be considered the same as fertilizer or machinery inputs because it is not controlled by the producer; it cannot be varied and does not create a quasi-rent. In that case, the welfare economic conclusions are quite different, although the case for government intervention in developing countries might be stronger on food security grounds.

We begin in the next section by briefly discussing the approach to price stabilization employed previously in the literature. This is followed in section 3 by a description of a revised approach. We find that the gains to producers from price stabilization are much greater than suggested by the early literature. Then, in section 4, we examine the food security issue in greater detail, concluding that a price stabilization policy can be justified in developing countries because, while it benefits producers, it can also prevent prices from rising to the extent that the most vulnerable individuals can no longer afford to buy food. However, the analysis also indicates that pure storage schemes will need to be supplemented by other policies, especially trade policies, to address food security issues. These issues are discussed further in a concluding section.

2. STANDARD APPROACH TO THE ECONOMICS OF STORAGE

In the standard framework, government intervention is required to stabilize agricultural markets. This generally requires the government to purchase a commodity when prices are low, store the commodity for a time, and then sell it when prices are high. The purpose in this case is to stabilize prices rather than raise them. The economics of storage are reviewed by Schmitz et al. (2010, pp.73-77) and their approach is followed here. We focus on the case of supply uncertainty because demand uncertainty is less likely to be an issue, especially for the types of commodities, namely cereal grains such as wheat, maize and rice, that are typically stored for price stabilization and food security purposes.

The use of a stock-holding stabilization scheme in the case of supply uncertainty can be illustrated with the aid of Figure 1. First, assume that the source of uncertainty is the price of an input such as fertilizer. Suppose the price of fertilizer can take on one of two values, each with equal probability ½. If the price of fertilizer is high, the supply function is S_1, but it is S_0 if the price of fertilizer is low; S_0 and S_1 occur with equal probability of ½. If futures prices embody knowledge of the demand function and also respond immediately to the price of fertilizer, the producer knows to produce q_0' when the price of fertilizer is low (S_0) and q_1' if the fertilizer price is high (S_1). In the former case, the variable cost of production is ($0kmq_0'$) and ($0gnq_1'$) in the latter (S_1) case. The expected consumer surplus in each period is ½(cmP_0 + cnP_1), while the expected producer surplus or quasi-rent is ½(kmP_0 + gnP_1).

When the government intervenes to stabilize prices through a storage program, producers no longer face prices that fluctuate between a low P_0 and high P_1, but they can plan on a stable price of P_e. To stabilize price at P_e, the authority buys the amount ($q_0 - q_e$) when S_0 occurs and sells ($q_e - q_1$) = ($q_0 - q_e$) when S_1 occurs. With stabilization, when S_0 occurs, consumers lose (P_0mbP_e), while producers gain (P_0mdP_e), with a net gain to society given by (bmd). When S_1 occurs, consumers would gain (P_ebnP_1) with stabilization while producers would lose (P_ehnP_1), with the net gain to society equal to (hbn).

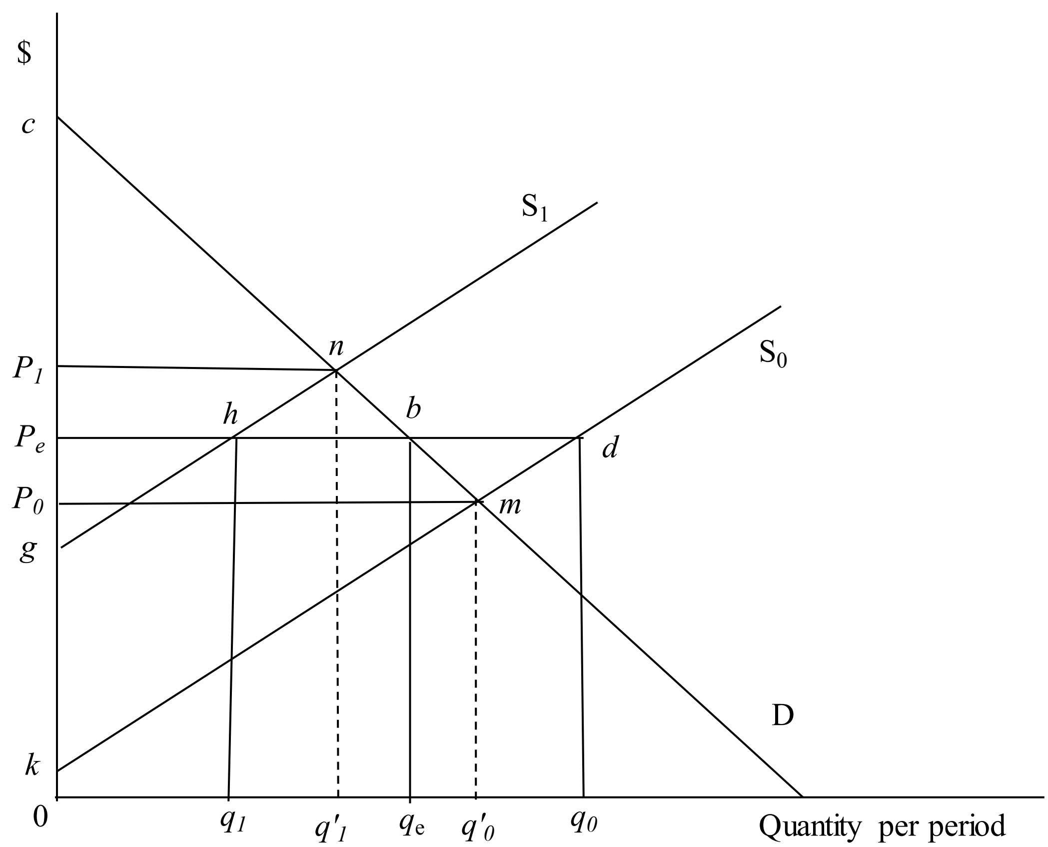

Figure 1: Buffer Stock Stabilization under Supply Uncertainty

The storage scheme leads to an average annual net gain of ½(*hbn* + *dbm*) minus administrative and storage costs. Thus it is deemed welfare improving. However, while producers are better off with the stabilization fund, their incomes are more variable than they would be in the absence of buffer fund stabilization; the surplus accrued by consumers, however, is unchanged from one period to the next, equaling (cbP_e) each period. In contrast, in a model of demand uncertainty, producers will prefer uncertainty to price stabilization while consumers prefer stable prices.

3. ALTERNATIVE MODEL OF BUFFER STOCK STABILIZATION

The problem with the standard model of stabilization is that uncertainty does not originate with the price of fertilizer, or the price of any other input for that matter. Nor is the main concern uncertainty on the demand side, because demand for grains tends to be rather inelastic, dependent on population and incomes, neither of which is likely to shift greatly from one year to the next. Rather, the uncertainty with which governments are most concerned is the result mainly of weather, although pests and disease may also be a worry. It is precipitation and moisture availability and heat during the growing season that are of greatest concern. If there is drought, crop yields are much reduced, while timely precipitation and adequate warmth can lead to bumper crops. Although the weather input affects supply and thereby welfare, it does not constitute a factor of production that agricultural producers can vary and combine in optimal fashion with other inputs. Quasi-rent cannot be attributed to weather factors.

If outcomes are the result of weather factors, the analysis in Figure 1 needs to be modified; this is done in Figure 2 (which duplicates some aspects of Figure 1). Acting independently and on expectations of the future price at harvest and normal weather conditions, the actions of grain producers will lead to the planning supply function S_P. If expectations are realized, the farmers will produce q_e. They will incur variable costs equal to ($0abq_e$), receiving a quasi-rent given by (abP_e). Regardless of the weather outcome, the variable cost incurred by producers does not change – weather affects yield outcomes and thus total revenue and what is available to offset against fixed costs. Generally, this would be the quasi-rent or producer surplus. In this case, however, the difference between total revenue and total variable costs consists of components of quasi-rent and rent, with the latter attributable to the weather factor.

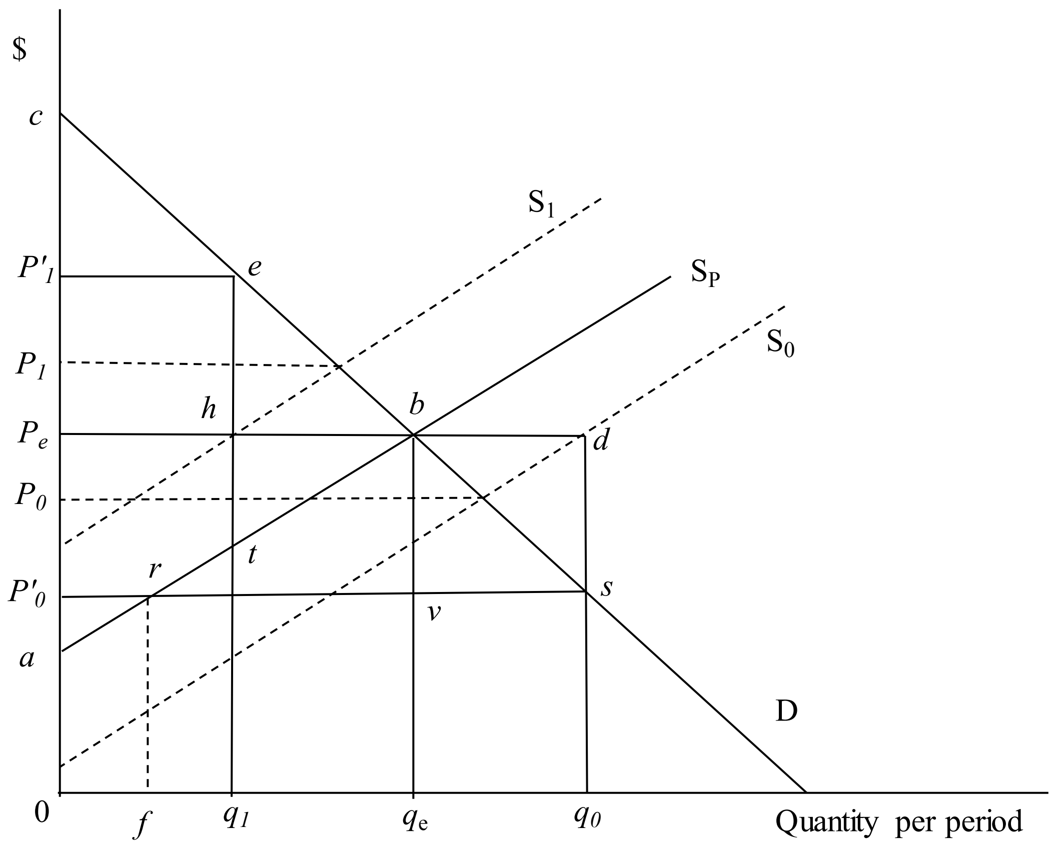

Figure 2: Buffer Stock Stabilization under Climate Uncertainty

Consider first the consumers. The expected consumer surplus is (P_ecb) except that the true consumer surplus will vary according to whether the weather-induced outcome is q_0 or q_1. Under q_1 the consumer surplus is ($P_1'ce$), while it is ($P_0'cs$) under q_0. If the government stabilizes price at P_e by storing amount ($q_0 - q_e$) (= distance bd) when S_0 occurs and selling ($q_e - q_1$) = hb = ($q_0 - q_e$) when S_1 occurs, the consumer surplus is (P_ecb) in every period. Because (P_ebsP_0') >

($P_e beP_1'$), consumers are worse off with storage that stabilizes price at P_e than they are if prices were left to fluctuate.

On the producer side, the economic surplus is given by the difference between total revenue and total variable costs. In the case of bad weather (outcome q_1), the surplus is given by $q_1P_1' - (0abq_e)$; in the case of good weather (outcome q_0), the surplus is given by $q_0P_0' - (0abq_e)$. The first question to ask relates to whether there is even a surplus under each of these conditions. Under a good weather outcome, the surplus is positive if (arP_0') + ($q_e vsq_0$) > (rvb); under a bad weather outcome, the surplus is positive as long as ($ateP_1'$) > (q_1tbq_e). Now there is no guarantee that there is a positive surplus in either outcome, although, from the diagram, it appears that it is more likely the case for the good weather outcome (q_0) than the bad one (q_1). It all depends on the elasticities of supply and demand and functional forms. However, it is clear that, under storage, producers are better off as they are guaranteed the expected quasi-rent of (abP_e); indeed, they might well be better off than indicated in the standard analysis.

The forgoing analysis is much starker than the standard one, because it indicates that agricultural producers can fail to recoup their investment costs under good or bad weather outcomes. This is one factor that has driven the desire for government intervention through storage. Although agricultural producers have an incentive to lobby for storage schemes, governments in developing countries may also have an incentive to store grain for political reasons. Despite the result that consumers are better off with price instability, the fact that prices fluctuate to a much greater extent in the alternative model than the standard one relates to food security concerns. Because expenditure on food accounts for a large proportion of household income in developing countries, and especially among the poorest people, governments are more sensitive to high prices (bad weather outcomes) than to low prices (good weather outcomes).

Indeed, in developing countries, agricultural policies seek to avoid bad outcomes in terms of high prices, whether the policy tools involve storage schemes or export bans (Meijerink and Joshi 2016).

4. THE MYSTERIOUS CASE OF DISAPPEARING GRAIN STOCKS, OR NOT

A second problem with the standard model concerns the assumption that stock holding in one period is always offset by sale of stocks in the next, as if governments have perfect foresight. Implicitly the model assumes that S_0 in Figure 1 (or q_0 in Figure 2) occurs first, followed by S_1 (q_1) in the next period, followed again by accumulation, and so on, so that stocks are held for only one period. Yet, a historic problem of U.S. and European Union agricultural support price policies was the increasing accumulation of stocks, which then had to be reduced or eliminated using various export incentive programs (van Kooten et al. 2018). Increasing stocks were the result of too many good years or too high a support price (the price at which the government would purchase stocks), or both. Even if the government set the support price as indicated in Figures 1 and 2, at the outset of such a program there could be several periods in a row where the weather outcome is bad and prices are high, or where it is good and prices are historically low. In these cases, a transition period is required. Even so, runs of good or bad years can have important implications for any stock holding scheme.

In this section, we consider the effectiveness of a price stabilization (stock-holding) program by comparing the potential welfare impacts of price instability versus price stabilization over a long period. To do so requires Monte Carlo simulation. Before doing so, however, we provide some background on stock holding of various grains.

Global Stock Holding and Prices of Major Grains

Globally, stocks of grains are important for reasons of food security. As indicated in

Figure 3, stocks dipped significantly after the late 1990s, reaching lows during the middle of the 2000 decade, before rising after 2010. Most of these stocks were held privately as part of the supply chain, although some governments, most notably India, held stocks as a component of agricultural policy to keep consumer prices affordable. As a proportion of consumption (or utilization as livestock consumption is distinguished from human consumption), stocks have risen over the past decade, so that rice and wheat stocks are more than 30% of consumption, while stocks of cereal grains exceed 25% and those of coarse grains, such as barley, are more than 20% of utilization (Figure 4). Nonetheless, declines in global food stocks are always a concern because they are indicative of poorer world-wide weather patterns (as can be caused by the eruption of a large volcano) and a harbinger of higher prices that will hurt those in least developed countries the most. This is evident when we look at prices, which have trended downward as stocks have increased, as indicated in Figure 5.

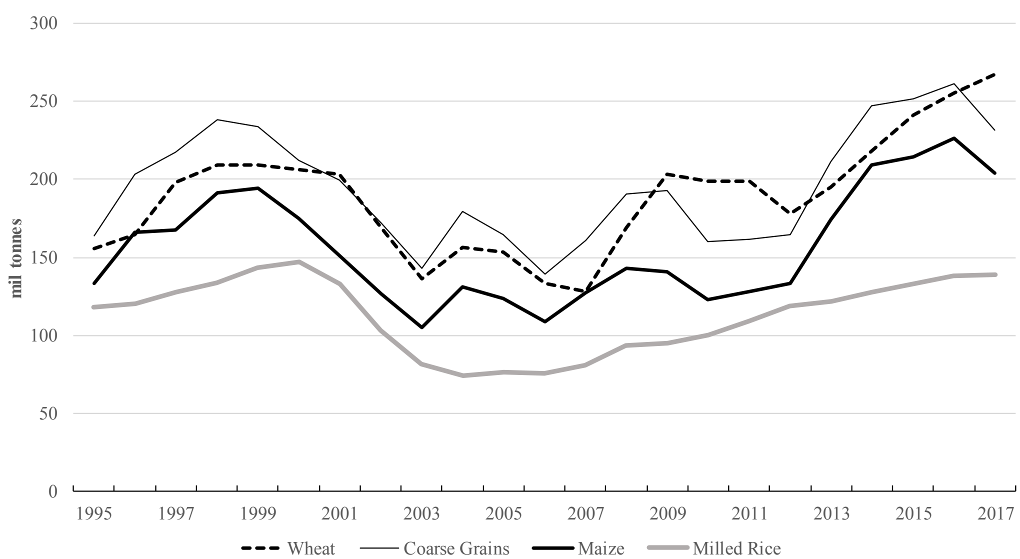

Figure 3: Ending Year Stocks of Selected Grains, 1995-2017

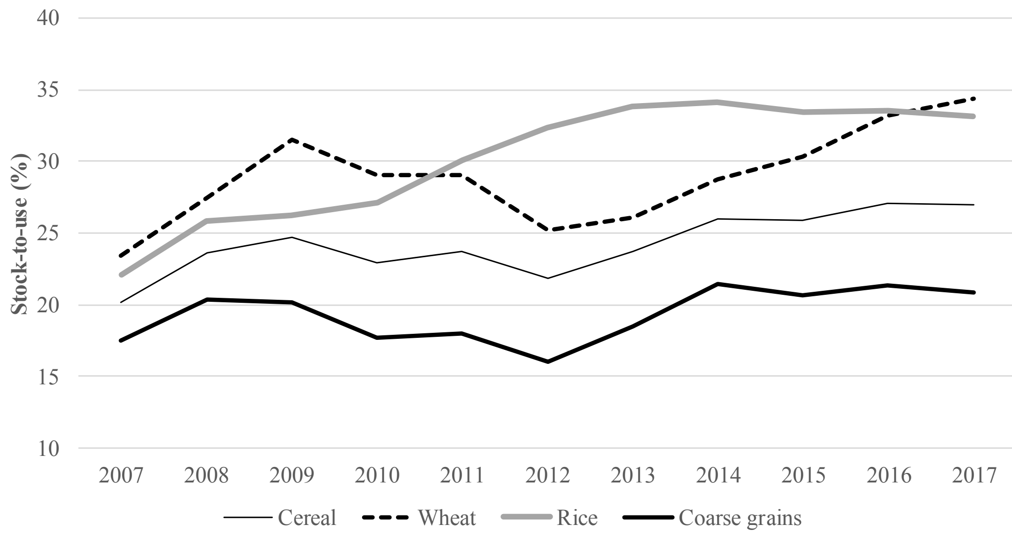

Figure 4: Global Stocks as a Proportion of Consumption, Selected Grains, 2007-2017

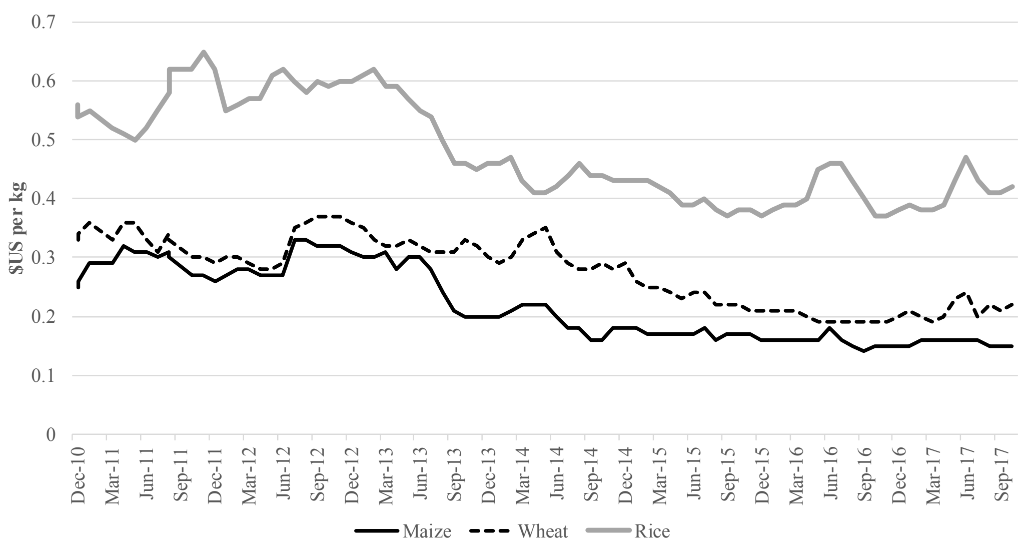

Figure 5: Global Average Monthly Prices of Rice, Wheat and Maize, 2010-2017

There is no effective correlation between global end-of-year wheat stocks and the average annual world price. The correlation between stocks and the price of the previous year is 0.21, but the simple correlation between stock holding/release and the price of wheat is -0.24 (Figure 6). The latter indicates that, as price goes up, there is a tendency to release stocks to keep prices down, as desired. In the simulation analysis that follows, we employ wheat stocks and prices to illustrate the impact of price stabilization (and stock holding/release) on welfare, and the differences between the standard model and the alternative presented above in relation to economic efficiency and the income re-distributional impacts of price stabilization.

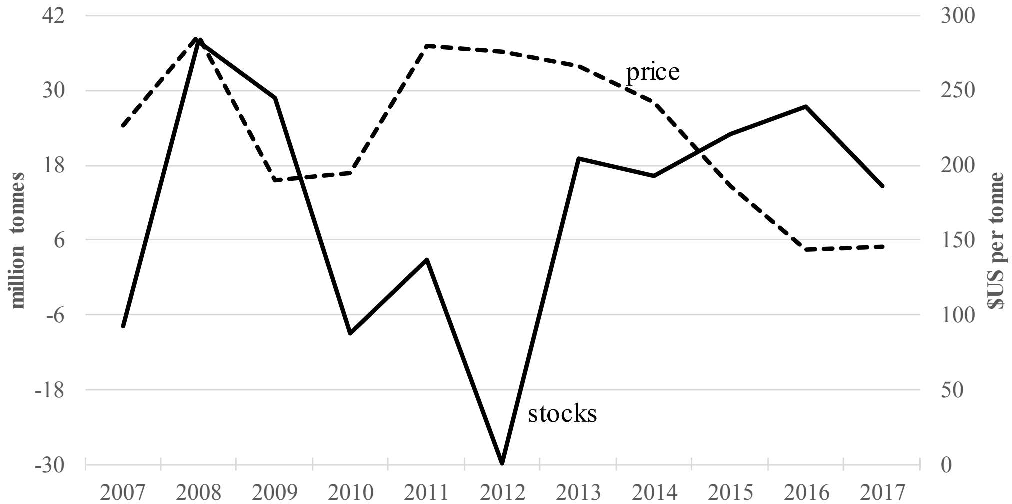

Figure 6: Price and Stock Holding or Release, Wheat, Global Data, 2007-2017

Simulating Efficiency and Income Distributional Effects

We employ a simulation model that uses a probability distribution to determine a series of outcomes regarding actual supply based on a planning supply function and given price. To address the traditional approach of stochastic supply, we choose a random number between 0 and 1. Then, if $p<0.5$ we have a bad weather outcome, and, if $p>0.5$, we have a good outcome. This leads to a binary probability outcome. Alternatively, we could employ a normal distribution over the possible outcomes, except a normal allows for a negative value; in lieu of a normal distribution, we employ a distribution that only allows positive values or simply employ a uniform distribution over the possible outcomes. The problem with a uniform distribution is that small departures from mean yields are treated as being just as likely as large departures. In the end, we employ the binary approach plus a triangular distribution whose parameters are determined by the expected supply, worst and best case supply outcomes.

One could just as well choose a continuous distribution over all possible outcomes between the worst and best weather outcomes. In that case, we employ a triangle distribution,

$$f(x) = \begin{cases} 0 & x < a \\ \dfrac{2(x-a)}{(b-a)(c-a)} & a \le x < c \\ \dfrac{2(b-x)}{(b-a)(b-c)} & c \le x \le b \\ 0 & x > b \end{cases}$$

where a is the minimum value that the random variable can take, b is the maximum value it can take, and c is the mode so that $a \le c \le b$. The mean of the triangle distribution is given by $(a+b+c)/3$ and the variance by $(a^2 + b^2 + c^2 - ab - ac - bc)/18$.

For the base simulation, we employ a model calibrated to 2009 global data on prices, production, demand and stocks; a second simulation uses a model calibrated to 2016 data. In 2009 (2016), global demand was 655.3 (732.8) million metric tons (t) and the average global price was US$190.1/t ($143.16/t). In 2009, production exceeded demand by 28.7 million tonnes, compared to 23.0 million t in 2016. The elasticity of demand for the base case simulation is assumed to be -0.3 while the elasticity of supply is 0.7; for the second (2016-based) simulation, we employ an elasticity of demand of -0.5 and elasticity of supply equal to 0.9 (see Jongeneel and Koning 2015).

There are three general scenarios:

1. Supply uncertainty with no attempt to stabilize prices. The supply curve is assumed to shift so that producer and consumer surpluses are calculated from the intersection of demand and the new supply function.
2. Supply uncertainty with no attempt to stabilize prices, but now the relevant supply curve continues to be the planning curve. Only the output differs due to weather factors.
3. Price is stabilized where the planning supply function and the demand function intersect.

For each, we examine a binary probability distribution and a continuous, triangle probability distribution. The results we present are the consumer and producer surpluses and the stocks held by the stock-holding entity, whether government or some other agent.

Stochastic Supply with No Price Stabilization

We begin with the results of supply uncertainty: The supply curve actually shifts so that quasi-rents are measured under 'new' supply curves versus the case where the supply function is fixed but the output is varied so that variable cost is measured under the planning supply curve and not a 'new' supply curve. Then for each of these we have the discrete and continuous probability functions. Notice that there is no stockholding as markets are assumed to clear.

First consider the case where quasi-rents are measured under the new stochastic supply curves. The total variable cost changes in this case unlike the case where the supply curve remains unchanged so that the agricultural producer incurs the same total variable cost in each period. The results are provided in Table 1. When new supply curves are considered, the difference between the binary and continuous probability simulations is small, with average price of about $182/t, consumer surplus of $212 billion, and quasi-rents of $78 billion when the model is calibrated to 2009; the averages of these three measures are substantially lower for the 2016-calibrated model – price equal to about $140/t, consumer surplus of $107 billion and producer surplus of $67 billion.

When the supply curve is fixed, average prices remain about the same as previously and so does the consumer surplus. However, the quasi-rents that accrue to producers are nearly half of what they were when it is assumed that the weather input is somehow variable. The reason for the reduction in producer surplus relates to the reduction in total variable cost (area under the supply curve) when the supply curve shifts downward as a result of good weather. The good weather outcome reduces variable costs more than a bad weather outcome raises them.

Finally, the theory in section 3 tells us that prices should be more variable when the supply function is fixed. This is indeed the case as indicated in Table 2. The coefficient of variation of price over the 1,000 simulations is significantly lower in the case where weather shifts the supply function and variable costs are measured under the new supply than when variable costs are measured only as an area under the planning supply function.

Stochastic Supply with Price Stabilization / Stockholding

Now consider the situation where price is stabilized at the intersection of the original (planning) supply function and the fixed demand function. To maintain this price, a private or public stock-holding authority must purchase excess production and store it, or sell the commodity out of storage. Thus, it is necessary to keep track of the inventory held in storage. Again we consider the binary and continuous (triangle) distributions and assume that randomness increases production by 50 million tonnes or decreases it by this amount. In the binary simulations, it is one or the other; with continuous probability, the increase or decrease is between these values using a symmetric triangle distribution. The average amount stored in each period under binary probability is -0.6 million t, while it is -0.7 million t under the continuous probability scenario. Although seemingly small, over 1,000 periods this amounts to some 600 to 700 million tonnes. However, as pointed out below, it is not average storage that is important. The stochastic scenario results are also provided in Table 1.

Table 1: Simulation Results, Average Prices, Consumer Surplus and Quasi-rent (Producer Surplus), 2009 and 2016 Calibrations, Various Scenarios

	Base 2009-calibrated simulation			2016-calibrated simulation		
Scenarios	Price ($/t)	Consumer surplus ($ bil)	Quasi-rent ($ bil)	Price ($/t)	Consumer surplus ($ bil)	Quasi-rent ($ bil)
			No stabilization			
New supply, binary	182.69	212.608	78.427	139.91	107.382	67.188
New supply, continuous	182.26	212.805	78.192	139.65	107.512	67.255
Fixed supply, binary	181.73	214.349	39.169	139.76	107.905	35.078
Fixed supply, continuous	182.44	212.863	41.538	139.75	107.503	35.889
			Price Stabilization			
Binary	182.02	212.948	81.796	139.48	107.620	68.869
Continuous	182.02	212.948	81.697	139.48	107.620	68.871

Source: Author's calculations

Table 2: Coefficient of Variation in Prices, Standard vs Alternative Approaches

Probability distribution type	Standard approach: Weather affects variable cost so supply functions shift	Alternative approach: Weather does not affect variable cost
	Base 2009-calibrated scenario	
Binary	5.70%	13.98%
Continuous	2.34%	5.73%
	2016-calibrated scenario	
Binary	7.66%	26.62%
Continuous	3.06%	10.58%

The results in Table 1 do not provide unqualified support for the notion that consumers will always lose from price stabilization, although gains or losses are at best small. However, producers clearly benefit from storage, although the standard model of storage underestimates the costs of random weather events compared to the alternative model. This is because the standard model treats weather as an input that agricultural producers can somehow adapt to by choosing a preferred level of the weather variable or, more realistically, chose other inputs in full anticipation of the weather outcome. Even the latter is not possible, of course, because weather during the growing season is unknown at planting time; even if it is somehow predictable, this would then be reflected in the planning supply function. Farmers benefit more from storage than indicated by the standard model. Further, it is clear from the numerical analysis that the gains to producers from storage are greater than any losses that might be incurred by consumers, which is less clearly the case in the standard model.

Storage schemes need to take into account the impact on the stockholding agency as well as on agricultural producers and consumers. The stockholder might need to accumulate stocks for a long period before being able to sell them, which implies rising costs of storage. Alternatively, the stockholder might need to conjure up the commodity to satisfy market needs at the stabilized price, although in practice the stockholder will raise the stabilized price in this case to ensure that markets clear to avoid queuing; in developing countries, however, queuing might nonetheless occur, or the government imports grain, as the authority is reluctant to increase the price. The potential for these circumstances to upset a straightforward price stabilization-stock holding scheme appears to be common, as indicated in Figure 7. Even under an ideally-designed stock-holding program, runs of increasing accumulation of stocks, or runs that require the authority to re-adjust the stabilized price, are not uncommon.

The results depicted in Figure 7 are less sensitive to the data used to calibrate the model than they are to the random seed employed. That is, random weather is the principal driver of stock holding and not the decisions of agricultural producers – average market conditions are not the main factor determining the storage levels required to stabilize prices.

Figure 7: Stock Accumulation under Binary (top) and Continuous (bottom) Probability Distributions for Weather Outcomes, 2016-based Scenario, Millions of Metric Tons

5. DISCUSSION AND CONCLUSIONS

Developing nations are concerned with food security, often using storage and export bans of major grains to ensure that food is affordable while yet providing adequate incentives to producers (Meijerink and Joshi 2016). While stock-holding is considered to benefit producers at the expense of consumers, the current study comes to a somewhat more nuanced conclusion. The model presented here indicates that prices fluctuate much more than indicated by standard model. Thus, the gains to producers from price stabilization are much greater than demonstrated using the standard approach to stabilization. Consumers on the other hand might not lose from price stabilization and, even where they do lose, reductions in consumer surplus are likely small and can easily be compensated by the gains to producers. More importantly for developing countries, a storage scheme can prevent prices from rising to the extent that the most vulnerable individuals can no longer afford to buy food. Thus, storage could benefit both producers and consumers in a developing country.

Who then pays the costs, because intervention in markets always comes at a cost (Harberger 1971)? Clearly, the stock-holder or authority incurs the costs of any price stabilization scheme. These are the transaction costs of administering the scheme and physically holding stocks that are subject to depredation by rodents and rot. Further, as shown here, there is no guarantee that stocks could accumulate over a significant number of periods or that there are insufficient stocks in storage to stabilize price. It is a political decision as to whether the government should be engaged in price stabilization, either holding stocks on its own or incentivizing private (on-farm) stock holding. It is likely that developing countries are more interested in stock holding than developed countries as the former have greater concern about food security in the form of unaffordably high prices.

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