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

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Abstract:
We revisit the underlying economics of commodity storage and its relation to food security by first clarifying the standard model used to analyze the economic efficiency and distributional effects of commodity storage programs. We find that producers prefer stabilization, although their incomes are more variable, while consumers are indifferent. However, numerical simulations indicate that physical stocks will build up inexorably over a sustained period or the government will need to raise prices continuously over a prolonged period. For the least developed countries facing fluctuating world prices, government should guarantee the price received by producers because, with price uncertainty, farmers could experience losses even under a 'good' weather outcome; this would guarantee the producer price, benefitting farmers, while allowing the consumer price to vary with the world price benefits consumers as they prefer price instability. In some cases, however, the government may wish to impose a price ceiling so that households living at or near subsistence can afford to buy grain – an argument based on the grounds of food security. Numerical simulations indicate that such a mixed-price policy increases the wellbeing of both consumers and producers. Physical storage is not a necessity.

Keywords: agricultural policy in developing countries, price stabilization and commodity storage, applied welfare economics

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

DOI: 10.1515/jafio-2019-0054

1 Introduction

There has been increasing interest in commodity storage programs in developing countries for reasons of food security (Meijerink and Joshi 2016; Schmitz and Kennedy 2016), with global stocks of grain remaining particularly important. As a source of carbohydrates, the most important crops for developing countries are, in rank order, rice, maize, and cassava. Because there is little or no information available on stocks of cassava, the discussion will consider rice, maize, and wheat (major food grains). While food security and price stability are reasons for public stockholding of grains, private grain traders and public entities often hold stocks simply to take advantage of intra-year price differences, thereby reducing the extent to which prices fall at harvest time and rise during other times of year. Stocks are held to take advantage of market conditions and for speculative purposes. Nonetheless, as we will show, some countries still hold stocks for operational and strategic (food security) reasons.

As indicated in Figure 1, global stocks of grain dipped significantly after the late 1990s, before rising after 2010. Most of these stocks were held privately as part of the supply chain, although some governments held stocks as a policy to keep consumer prices affordable. As a proportion of consumption, stocks have risen over the past decade, so that rice and wheat stocks account for more than 30 % of consumption; stocks of cereal grains exceed 25 %; and those of coarse grains, such as barley, exceed 20 % (Figure 2). Nonetheless, declines in global food stocks are always a concern because they are indicative of poorer global 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 (Figure 3).

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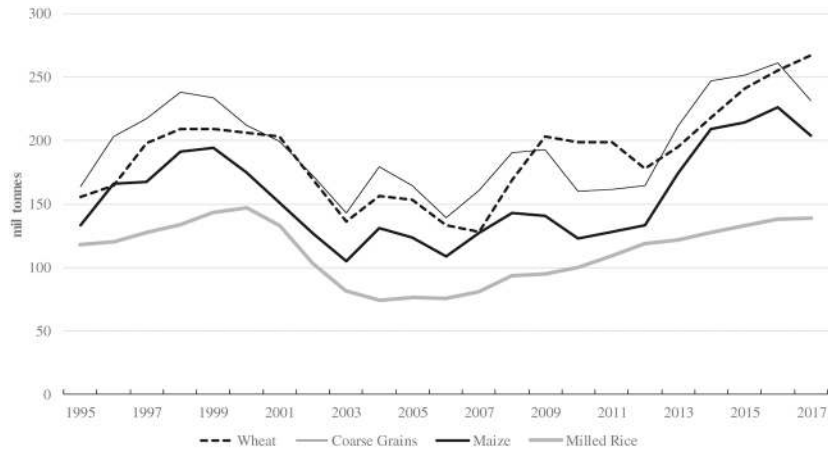

Figure 1: Ending year stocks of selected grains, 1995–2017.
Data source: U.S. Department of Agriculture (USDA).

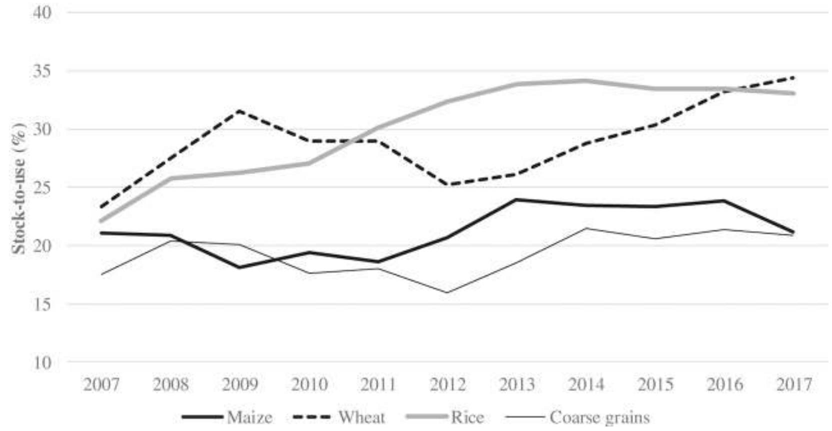

Figure 2: Global stocks as a proportion of consumption, selected grains, 2007–2017.
Data source: UN Food & Agriculture Organisation and USDA.

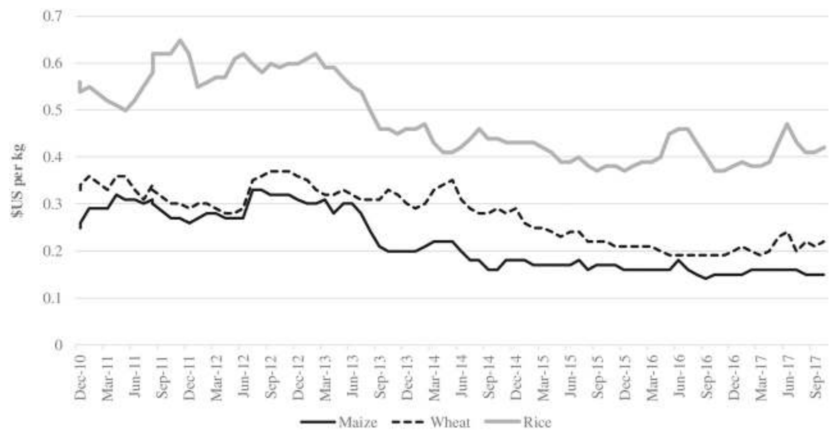

Figure 3: Global average monthly prices of maize, wheat, and rice, 2010–2017.
Data from International Food Policy Research Institute (IFPRI).

There is no effective correlation between global end-of-year maize stocks and the average annual world price. The correlation between stocks and the price of the previous year is 0.25, but the simple correlation between stockholding/release and the price of maize is 0.43 (Figure 4), with the latter indicating, counterintuitively, that there is a tendency to purchase stocks as prices go up, perhaps out of fear of further price increases. For wheat, the correlation between stocks and the previous-year price is also positive (0.21), while the simple correlation between stock variation and price is essentially zero. However, none of these correlations is very significant.

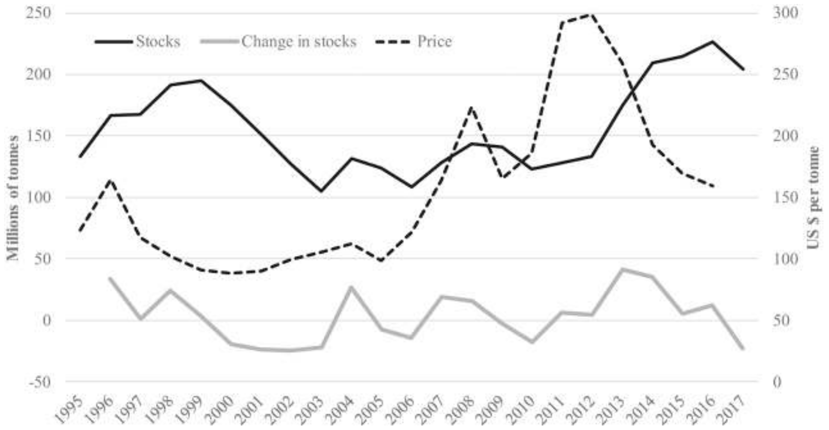

Figure 4: Price and stockholding or release, maize, global data, 1995–2017.
Data from USDA and IFPRI.

We now consider instead of global stocks, holdings in a small Sub-Saharan African country. A somewhat different picture emerges. Consider, for example, Rwanda, which is a land-locked, developing country, with about 12 million inhabitants and a population density of over 440 persons per square kilometer (km), where 70 % of its people are engaged in agriculture. Agriculture accounts for about one-third of the country's gross domestic product (GDP). Tea and coffee are the main export crops, with plantains, cassava, potatoes, sweet potatoes, maize, and beans also grown and even exported, but mainly to neighbouring countries. The most important grain is maize, which can easily be stored and traded on international markets. Production, consumption, imports, and year-end stocks of maize for Rwanda are illustrated in Figure 5. Data for production, consumption, and imports (some maize is exported but amounts are tiny compared to imports) are for 1994 through 2018, while stock data are only available since 2008.

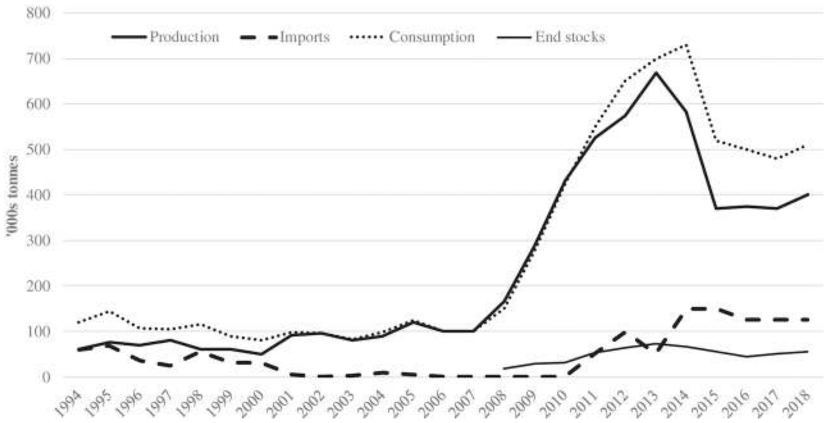

Figure 5: Maize production, consumption, imports, and ending stocks, Rwanda, 1994–2018.
Data sources: UN Food & Agriculture Organisation and USDA.

As indicated in Figure 6, in Rwanda domestic prices for maize varied between 12.4¢ and 41.1¢ per kilogram (kg) (U.S. currency) in nominal terms during the period 1991 to 2016, while import (export) prices varied from 8.1¢ to 79.4¢ per kg (2.0–60.0¢/kg), although exports were insignificant compared to imports. The simple correlation coefficient between the change in stocks in any year and the previous-year price of maize is −32.8 %, indicating that when prices were high (low), stocks were reduced (increased), as expected. The correlation between changes in price and changes in stocks is nearly zero, and that between prices and stocks is statistically insignificant, partly because data are only available for nine years.

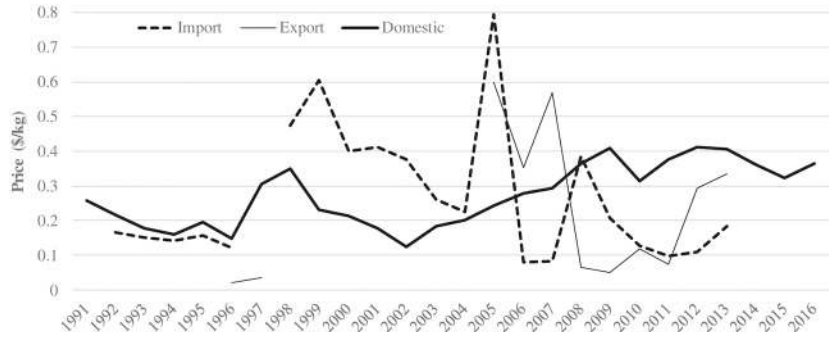

Figure 6: Domestic price and value of imports and exports, maize, Rwanda, 1991–2016.
Data from International Food Policy Resarch Institute.

In this paper, we revisit the underlying economics of commodity storage by introducing food security concerns. We begin by re-examining the standard model used to analyze the economic efficiency and distributional effects of commodity storage programs in the case of a large country where stockholding from one period to the next affects prices. We consider the case of stochastic supply because demand from one period to the next is generally quite stable, while supply can be highly uncertain. In the standard framework, government purchases a commodity when prices are low, stores the commodity for a time, and then sells it when prices are high. The purpose of stocks in this case is to stabilize prices. In analyzing instability due to supply uncertainty, producers are found to be better off under stabilization, but their incomes are more variable than in the absence of storage, while consumers are indifferent; conversely, if demand is stochastic, producers will prefer uncertainty to price stabilization, while consumers prefer stable prices (see Schmitz et al. 2010, 73–77).

We demonstrate with a numerical example that physical storage can be a problem when there are prolonged periods of good or bad weather. We address stabilization under both the large- and small-country assumptions. A very small country can rely on internal price policies and global stockholding to address food security concerns. In particular, the country can purchase and sell grain at the world price to stabilize the domestic prices that incentivize producers and prevent starvation and malnutrition. That is, we consider what amounts to a monetary buffer fund. Next, we examine the case where a country uses physical holding of stocks to achieve food security objectives, but avoids the pitfall of accumulating stocks or the need to increase domestic prices over a prolonged period. While the discussion is primarily analytic, simulation is employed in some cases to support our insights. Our analyses indicate that pure storage schemes work only in restricted cases, and even then would need to be supplemented by other policies, especially trade policies, to address food security issues.

2 A Model of Buffer Stock Stabilization

The uncertainty with which governments are most concerned is the result mainly of weather, although pests and disease are also problematic. It is precipitation/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.

2.1 Analytical Model of Storage

In Figure 7, we provide an analysis of storage when outcomes are the result of weather factors. Assume that q_0 and q_1 represent different weather outcomes that occur with equal probability. 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. Normally, 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 weather factor.

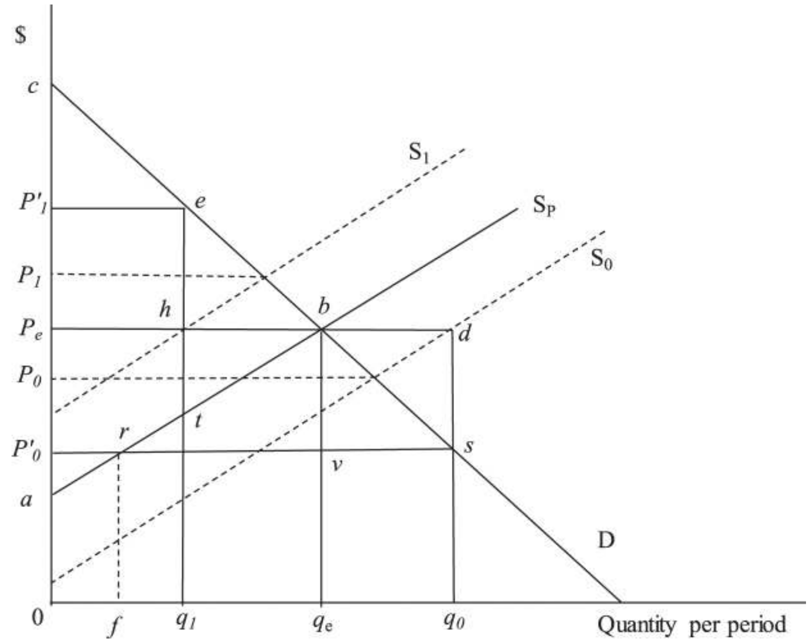

Figure 7: Buffer stock stabilization under climate uncertainty.

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_ebeP_1'), consumers are worse off with storage that stabilizes price at P_e than they are with price instability.

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 $q_1 \times P_1'-(0abq_e)$; in the case of good weather (outcome q_0), the surplus is given by $q_0 \times P_0'-(0abq_e)$. 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_evsq_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 for the bad one (q_1). It all depends on the elasticities of supply and demand and functional forms. However, it would appear that, under storage, producers are better off, mainly because they are guaranteed the expected quasi-rent of (abP_e) and because of the symmetry assumed in the model. Without symmetry, there is no reason that producers are better off or worse off.

The foregoing analysis indicates that agricultural producers can fail to recoup their investment costs under good or bad weather outcomes. Producers may be better off with storage because they could fail to recoup any quasi-rent without it, and therefore they may have a greater incentive to lobby for government intervention than the usual argument for storage would suggest. Meanwhile, consumers are better off with price instability.

2.2 Simulation Model

To illustrate the extent of the gains and for simplicity, we assume a very large country whose agricultural policies set world prices, in this example, the global price of wheat. The country stabilizes price by holding stocks according to the mechanism depicted in Figure 1; our purpose is to examine the welfare distributional consequences of price stabilization. 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 tonnes (Mt) and the average global price was US$190.10/tonne (t) ($143.16/t). In 2009, production exceeded demand by 28.7 Mt, compared to 23.0 Mt 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).

In the simulation models, we employ probability distributions to determine a series of outcomes regarding actual supply based on a planning supply function and given price. To address stochastic supply, we choose a random number between 0 and 1. Then, if $p < 0.5$, we have a bad weather (high price) outcome, and, if $p > 0.5$, we have a good weather (low price) outcome. This leads to a binary probability outcome. Alternatively, we could employ a normal distribution over the possible outcomes, except that it allows for a negative value; in lieu of a normal distribution, we employ a distribution that only allows positive values. We could simply employ a uniform distribution over the possible outcomes, but this assumes that small departures from mean yields are treated 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 (expected price), and the worst and the best case outcomes. The triangular distribution is specified as follows:

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

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 $a \leq c \leq b$. The mean of the triangle distribution is given by $(a + b + c)/3$ and the variance by $(a^2 + b^2 + c^2 - ab - ac - bc)/18$.

The stabilization price is determined by the intersection of the planning supply function and the demand function based on the foregoing elasticities of supply and demand. Then, 1,000 weather outcomes are simulated for each of a binary probability distribution and a continuous, triangular probability distribution about the weather outcome. We begin with the results for supply uncertainty; it is assumed that randomness increases production by 50 Mt 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 triangular distribution. The supply function is fixed so that variable cost is measured under the planning supply curve with the agricultural producer incurring the same total variable cost in each period, while consumer surplus varies with price outcomes. Initially, there is no stockholding as markets are assumed to clear. The results are provided in the top portion of Table 1.

Table 1: Simulation results, average prices, consumer surplus, and quasi-rent (producer surplus), 2009 and 2016 calibrations, various scenarios.

Scenarios	Base 2009-Calibrated Simulation			2016-Calibrated Simulation		
	Price[a] ($/tonne)	Consumer Surplus ($ billions)	Quasi-rent ($ billions)	Price[a] ($/tonne)	Consumer Surplus ($ billions)	Quasi-rent ($ billions)
			No Stabilization			
Binary probability	181.73 (5.70 %)	214.349	39.169	139.76 (7.66 %)	107.905	35.078
Continuous probability	182.44 (2.34 %)	212.863	41.538	139.75 (3.06 %)	107.503	35.889
			Price Stabilization			
Binary probability	182.02	212.948	81.796	139.48	107.620	68.869
Continuous probability	182.02	212.948	81.697	139.48	107.620	68.871

[a]Coefficient of variation of price is given in parentheses for the no stabilization scenario. It is zero for the price stabilization model.
Source: Authors' calculations.

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 stockholding 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 same binary and continuous (triangular) distributions and use the same random number of seed. The average amount stored in each period under binary probability is −0.6 Mt, while it is −0.7 Mt under the continuous probability scenario.[1] Although seemingly small, this amounts to some 6–7 Mt over a decade, and possibly a lot more as variance is significant. Further, as noted in the next subsection, it is not average storage that is important. The stochastic scenario results are provided in the lower portion of Table 1.

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. It is also clear from the numerical analysis that the gains to producers from storage are greater than any losses incurred by consumers.

2.3 The Mysterious Case of Disappearing Grain Stocks, or Not

One problem with storage models concerns the assumption that stockholding in one period is always offset by the sale of stocks in the next period, as if governments have perfect foresight. Implicitly, the model assumes that q_0 in Figure 7 occurs in the first period, followed by 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 EU agricultural price-support policies was the increasing accumulation of stocks, which then had to be reduced or eliminated using various export incentive programs (van Kooten, Orden, and Schmitz 2019). 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 Figure 7, 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 stockholding scheme.

Clearly, 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 (which ought not to be confused with a support 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 price. The potential for these circumstances to upset a straightforward price stabilization-stockholding scheme appears to be common, as indicated in Figure 8.

Figure 8: Stock accumulation under binary (top) and continuous (bottom) probability distributions for weather outcomes, 2016-based scenario, million tonnes (Mt).
Based on data from authors' simulation model.

In Figure 8, we employ information on global wheat stocks. In 2016, global demand was 732.8 Mt and the average global price was US$143.16/t, while production exceeded demand by 23.0 Mt We then assume that price and consumption remain unchanged, while production varies randomly between 750.8 and 805.8 Mt per year, or by ± 50 Mt annually. A predilection toward positive stock accumulation, which is the difference between production and consumption, is built into the model (as indicated by the 23.0 Mt surplus). The upper panel in

Figure 8 assumes that production each year is at the lower or upper bound with equal probability, while the lower panel employs a continuous, symmetric triangular distribution centered on 755.8 Mt in the simulations.

The results depicted in Figure 8 indicate that even under an ideally designed stockholding program, runs of increasing accumulation of stocks, or runs that require the authority to re-adjust the stabilized price, are not uncommon. It is clear, however, that random weather is the principal driver of stockholding and not the decisions of agricultural producers – average market conditions are not the main factor determining the storage levels required to stabilize prices. We examine two ways to get around this problem.

3 Food Security and Price Stabilization in a Small Developing Country

In developing countries, there is significant uncertainty pertaining to agricultural commodity prices. In the large-country model discussed above, a country storage policy can affect commodity prices, as can agricultural policy generally. However, in the model discussed below, the country using a stock policy is a price taker, as its policy action does not affect world prices.

3.1 Analytical Model of Price Stabilization for a Small Country in the Absence of Physical Storage

We analyze the economics of price stabilization in a small, open economy. In Figure 9, (P^*, q^*) represents the domestic price and quantity in the absence of trade – the intersection of domestic supply and demand at *e*. However, the country is a price taker, facing global prices for the commodity and these vary between P_0 and P_1, with an expected value $\bar{P}$. For simplicity assume P_0 and P_1 occur with equal probability of ½.

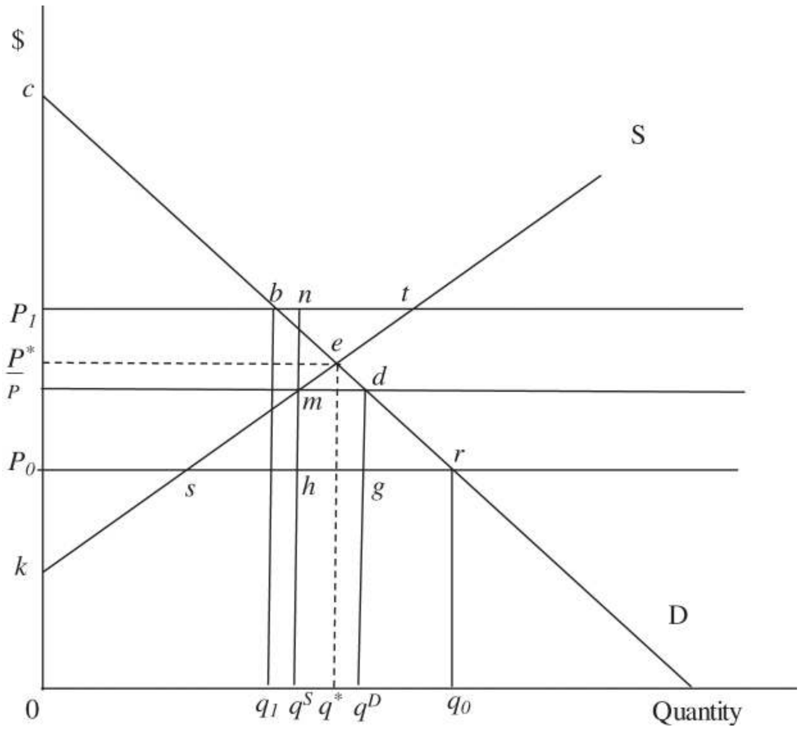

Figure 9: Price stabilization in a small, open economy.

Agricultural producers will produce q^S in each period because they base their decisions on the expected price $\bar{P}$. Thus, with price stabilization, if the global price is P_1, producers lose ($\bar{P}mnP_1$), but consumers gain ($P_1bd\bar{p}$). Conversely, if global price turns out to be P_0, producers gain ($\bar{P}mhP_0$), while consumers lose ($\bar{P}drP_0$). Overall, consumers are worse off with price stabilization as they would lose an average of ½×(*drg*) in each year, while producers would be just as well off with or without price stabilization. The result that consumers are worse off with stabilization while producers are neither better nor worse off holds even if the small country is a net importer at both prices P_0 and P_1.

There is another case to consider, however. Given that producers are no worse off with or without price stabilization, the authority in a small country might still seek to stabilize price to reduce the variability of producer incomes. At the same time, the government might allow consumers to continue purchasing at the world price as they are better off without than with stabilized prices. The effect of this policy could also reduce imports from *hr* (when P_0 occurs) minus *bn* (exports under P_1) to 2 × *md* over two periods; there is a reduction in imports with stabilization as long as $hr > bn$. The only drawback is that consumer expenditure on food, while lower than under price stabilization, is more variable and, in some cases, prices could be so high as to result in malnutrition as some families are unable to purchase sufficient food. The latter problem can be avoided by capping the price of food. These policies are further investigated using numerical simulation in the next subsection.

While the above analysis applies to any small, open economy, the case of a least developed country (LDC) might be different. The optimal policy for a small LDC might yet turn out to be price stabilization even though the forgoing analysis indicates consumers are worse off with stabilization while producers are indifferent. The reason is that expenditure on food accounts for a large proportion of household income in developing countries, especially among the poorest people; thus, governments are more sensitive to high prices (bad weather outcomes) than to low prices (good weather outcomes). Suppose that, at any price above *P*, the poorest in society are no longer able to purchase enough food to avoid malnutrition or starvation. Without price stabilization, if the global price were P_1, domestic consumption would fall to q_1, with some citizens consuming too little food while producers would export $q^S - q_1$ (= distance *bn*). To avoid the higher price, the authority would need to ban exports and import an amount given by *md* ($= q^D - q^S$). In practice, some countries have indeed used a combination of export restrictions and purchases on global markets to avoid bad outcomes in terms of high prices, thereby preventing malnutrition or starvation and urban unrest (e. g. see Meijerink and Joshi 2016). A price stabilization program may be adopted to forestall this.

3.2 Simulating Efficiency and Income Distributional Effects

In this section, we consider the effectiveness of a price stabilization program as described in Figure 9. We compare the economic efficiency and income re-distributional impacts of price stabilization in a Sub-Saharan African LDC, using maize data for Rwanda to parameterize the simulation model. Importantly, while our LDC could employ some storage, the current model considers only a monetary buffer fund type of approach. An alternative approach is also presented.

The domestic price of maize in Rwanda averaged 36.2¢/kg over the past decade, ranging from a low of 29.3¢/kg to a high of 41.1¢/kg, while import prices averaged 22.9¢/kg with a range of 8.1¢ to 79.4¢/kg, and export prices averaged 27.3¢/kg with a range of 5.1¢ to 56.9¢/kg. Domestic production averaged about 410,000 t annually, with imports of around 55,000 t, so domestic consumption averaged 465,000 t. Given information about elasticities, it is possible to construct linear supply and demand functions. For convenience, we assume that the elasticities of demand and supply are randomly chosen from triangular distributions given as [−0.3, −0.5, −0.9] and [0.7, 0.9, 1.5], respectively, where the first and last values are the endpoints of the distribution and middle values are the means. Finally, we assume that the global price of maize fluctuates randomly between 15.0¢/kg and 70.0¢/kg, while the Rwandan government does not permit the domestic price of maize to exceed 42.5¢/kg in one scenario and 40.0¢/kg in another so as to avoid potential political unrest and perhaps malnutrition.

In this case, there is no storage, but governments hold domestic price constant by exporting or importing grain on world markets as needed. The Monte Carlo simulation proceeds by first choosing 1,000 possible outcomes of the global price for each of the binary and continuous probability distributions. For each outcome, we draw 1,000 elasticities of supply and demand from their respective triangular distributions, and calculate production, consumption, prices, exports, imports, consumer and producer surpluses, and costs to the government (from purchasing maize abroad in extreme circumstances). For the binary model, a global price that is randomly determined to be 15.0¢/kg or 70.0¢/kg with equal probability, or, for the continuous model, chosen randomly from a triangular distribution with endpoints 15.0¢/kg and 70.0¢/kg and mode of 35.0¢/kg. A schematic of the Monte Carlo procedure is provided in Figure 10 and results are provided in Table 2 and Table 3.

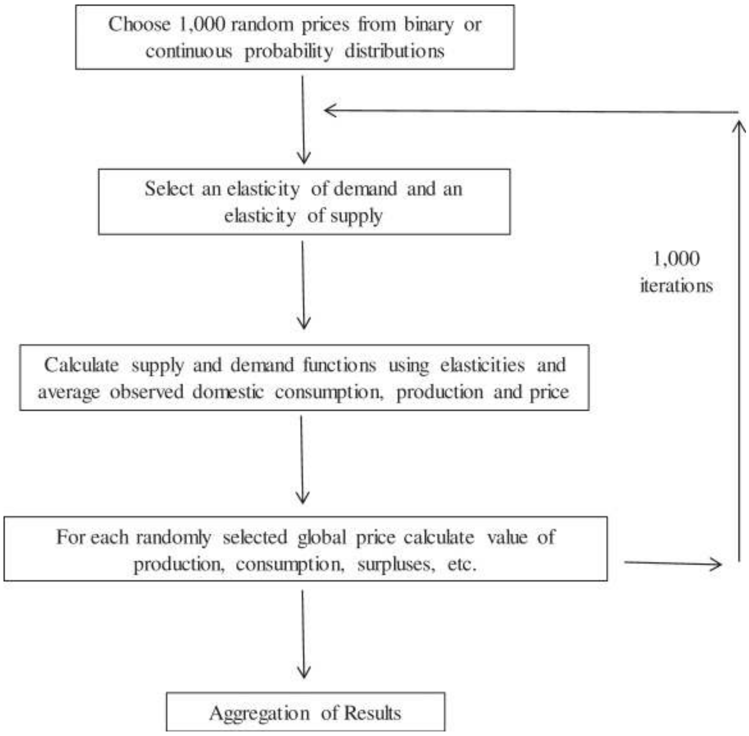

Figure 10: Schematic of Monte Carlo simulation.

Table 2: Selected mean values and coefficients of variation, with and without price stabilization, with and without minimum domestic prices, binary probability model[a].

Item	Without Price Stabilization		With Price Stabilization and Price Ceiling					
			None		$0.425/kg		$0.40/kg	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Price ($/kg)[b]	0.406	0.288	0.406	0.288	0.293	0.469	0.280	0.447
Consumption (t)	433,377	0.200	433,377	0.200	515,333	0.200	524,760	0.179
Production (t)	461,055	0.299	461,055	0.018	496,755	0.029	496,755	0.029
Exports (t)	104,702	1.397	49,653	1.281	40,237	1.010	30,810	1.027
Imports (t)	77,024	1.412	21,975	1.652	58,816	1.133	58,816	1.133
Consumer surplus ($$10^3$)	143,118	0.424	143,118	0.424	197,674	0.402	203,232	0.368
Quasi-rent ($$10^3$)	100,488	0.570	105,802	0.366	186,811	0.315	190,090	0.293

[a]Based on binary probability distribution with 1,000 × 1,000 scenarios.
[b]Domestic price which equals international price in absence of price stabilization.
Source: Authors' calculations.

Table 3: Selected mean values and coefficients of variation, with and without price stabilization, with and without minimum domestic prices, continuous probability model[a].

Item	Without Price Stabilization		With Price Stabilization and Price Ceiling					
			None		$0.425/kg		$0.40/kg	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Price ($/kg)[b]	0.408	0.269	0.408	0.269	0.370	0.180	0.359	0.161
Consumption (t)	431,621	0.191	431,621	0.191	459,186	0.108	467,373	0.092
Production (t)	462,868	0.279	462,868	0.019	464,739	0.019	464,739	0.019
Exports (t)	100,540	1.384	50,121	1.235	23,929	0.957	15,743	0.960
Imports (t)	69,293	1.494	18,875	1.815	18,377	1.832	18,377	1.832

Consumer surplus (10^3)	138,943	0.417	138,943	0.417	154,770	0.315	159,599	0.291
Quasi-rent (10^3)	100,415	0.534	105,541	0.351	112,768	0.273	116,739	0.240
Government cost (10^3)[c]	–	–	–	–	–	–	84.820	55.139

[a]Based on binary probability distribution with 1,000 × 1,000 scenarios.
[b]Domestic price which equals international price in absence of price stabilization.
[c]Averaged over 494 scenarios where payouts were warranted and not over all iterations.
Source: Author's calculations.

The results in Table 2 and Table 3 indicate that consumers are no worse off with price stabilization than without stabilization, while producers are better off with price stabilization than without. Given that the price chosen for stabilization is an average of the price in any one set of iterations (Figure 10), we consider two additional scenarios where the government imposes a domestic price cap that the stabilized price cannot exceed (Table 2 and Table 3). *This is done to enable even the poorest in society to purchase food and thereby prevent malnutrition. Not surprisingly, consumers gain even more surplus at the expense of producers if there is a price cap*.

Producers are better off with price stabilization than without, but, in the event of a price cap, they appear to be even better off with price stabilization. This is illusionary, however, because with a cap on the stabilization price, the apparent loss in quasi-rent is smaller (compared to no intervention), yielding a larger net producer surplus than without the price cap. That is, area ($\bar{P}mnP_1$) in Figure 9 is smaller because P_1 now represents the price cap. Without price stabilization, a price cap is likely to make producers worse off (Table 3), although this appears to be dependent on the type of probability distribution that is assumed to drive price risk (compare Table 2 and Table 3).

We now consider average prices, exports and imports with and without price stabilization, and with and without a cap on domestic price. Not surprisingly, if the government chooses to cap the price that consumers pay, average consumer surplus is higher; however, it turns out that producers are also better off in this case, although the reason is somewhat deceiving. When a stabilization program is in place along with a price cap to prevent the poorest in society from being malnourished, producers benefit because it is assumed that they would have received the lower price, thereby with a guaranteed (stabilized) price their loss is smaller than it would otherwise be.

Consider the binary probability case in Table 2. Quasi-rent is $105.8 million when price is stabilized, compared to $100.5 million when it is not. This implies that producers gain $5.3 million. Introduction of a price cap will, conversely, lower average price under a price stabilization scheme (and significantly so in the binary probability model), but leave it unchanged (binary) or raise it (continuous) if there is no policy to stabilize prices. The variability in price is higher for the binary price probability model, both with and without stabilization, and is lower in the continuous probability model but only if price is stabilized.

Average exports and imports are both significantly higher without than with price stabilization. With a stabilization program, average exports fall while imports increase or remain close to their original level as a price cap is implemented.

Finally, the cost of price caps is born primarily by producers who lose quasi-rent because they do not receive the world price for any maize that they then must sell domestically. The government only incurs costs when imports are particularly large, which occurs rarely, but when it does can be costly – the average annual cost is small ($42,000). However, this ignores the fact that, when global prices are high, domestic production might also be low, but the model we employ assumes a constant annual level of domestic production determined by the authority (as an average of model-determined random prices).

4 Discussion and Conclusions

Developing nations are concerned with food security, often using export bans and public purchase of imports of major grains to ensure that food is affordable while yet providing adequate incentives to producers (Meijerink and Joshi 2016). While price stabilization is considered to benefit producers at the expense of consumers, the current study comes to a somewhat more nuanced conclusion. The models presented here indicate consumers 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. Producers may well gain from price stabilization, commodity storage programs, but this is not conclusively so. For example, in a standard storage model (Figure 7), producers could potentially reap large rents depending on particular weather outcomes and the elasticities of demand and supply, but they would prefer the more certain quasi-rents associated with stabilization. More importantly for developing countries, however, price stabilization policies can prevent prices from rising to the extent that the most vulnerable individuals in society can no longer afford to buy food. Thus, stabilization programs 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, if there is stockholding, there are transaction costs of administration and physically holding stocks that are subject to depredation by rodents and rot. In the case of price stabilization, the authority incurs the costs of purchasing imports if world prices exceed the domestic price. These costs are generally quite low because countries rarely set domestic prices lower than world prices; further, some costs can be shifted onto producers (who benefit from stabilized prices in any event) by banning exports in those cases.

Finally, the results indicate that it would be difficult to use physical stockholding as a policy to stabilize prices, even in the large-country case considered in early models of storage. There is no guarantee that stocks would not accumulate over a significant number of periods, or that there would be sufficient stocks in storage to stabilize price. Conversely, price stabilization can be made to work in a small economy, or even a large, open economy, using such economic instruments as export bans and import purchases (essentially subsidies to consumers) without the need for physical storage.

It is a political decision as to whether the government should be engaged in price stabilization, or even stockholding on its own or incentivizing private (on-farm) stockholding. It is likely that developing countries are more interested in price stabilization and storage than developed countries as the former have greater concern about food security in the form of unaffordable high prices. Yet, public storage may be an anachronistic means for achieving price stability in a modern context where grain is easily traded and knowledge of plantings and potential yields is broadly available across the globe. Countries are turning increasingly to crop yield insurance and weather indexed insurance to protect agricultural producers from vagaries in weather and other natural perils.

Acknowledgements

The author wishes to thank Linda Voss for helpful comments and assistance.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Notes

1 Iterations are not temporally linked, and it is assumed there is always sufficient inventory in storage needed to keep price stable.

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