In the long view, recent volatility of prices of the major grains is not anomalous. Wheat, rice, and maize are highly substitutable in the global market for calories, and when aggregate stocks decline to minimal feasible levels, prices become highly sensitive to small shocks, consistent with the economics of storage behavior. In this decade, stocks declined due to high global income growth and biofuels mandates, making markets unusually sensitive to subsequent unanticipated shocks, including biofuels demand boosts in reaction to high petroleum prices, the Australian drought, and other regional grain production problems. To protect their own vulnerable and politically influential consumers, key exporters restricted supplies in 2007, exacerbating the price rise. Understandably, vulnerable importers are now building strategic reserves. To reduce costs and disincentive effects, reserves should have quantitative goals related to targeted distribution to the most vulnerable in severe emergencies. For countries with significant animal feeding or biofuels industries, options contracts to protect the consumption of the most vulnerable from harvest shocks are likely to be more cost-effective than emergency reserves.

1. Introduction: The Food Price Crisis of 2007/08 and the Re-emergence of Concerns over Commodity Price Volatility

The increases during 2007/08 in the prices of many consumption commodities, including the major grains, came as a shock to consumers and governments. Millions of the world’s poor were likely forced to reduce their daily calorie intake, and urban consumers participated in protests, often violent, that placed serious pressure on governments in developing countries.
In response, many nations adopted short run policies to reduce the effects of rising world prices on domestic consumers. Though perhaps rational for each country acting individually, these policies exacerbated international price volatility, and often penalized the domestic farmers and traders whose supplies to the market prevented more serious shortages. To make matters worse, importers’ concerns about food market access were heightened by news that key rice exporters were discussing the possibility of an export cartel.2

Grain prices have receded significantly from their 2008 highs. But food prices remain volatile.3 The policy focus has switched from short-term tactics for crisis management to strategies to manage price volatility and assure that consumers worldwide not be denied access to the grain they need. Global grain reserves have figured prominently in international discussions (United Nations, Food and Agricultural Organization, 2009). Proposals have been made for special emergency reserves, international reserves, and “virtual reserves” controlled via commodity futures and options trading. Some observers have also recommended regulation of commodity futures trading by noncommercial investors. Others have pressed for reductions in subsidies or mandates for biofuel production, on the grounds that such policies threaten the stability of food markets.

This paper addresses the role of grain reserves and related policies in managing grain market volatility. It is obviously important to begin with questions about the nature of the problem and its underlying causes. Are we witnessing the beginning of a new regime characterized by more volatile, if not higher, commodity prices? Is the recent turmoil in prices an aberration, involving irrational bubbles, unconnected to market fundamentals? Does it reflect purposeful manipulation by global monopolies? What have been the roles of futures and options markets, noncommercial speculators, and global international financial flows in all this?

Or is global warming already changing the volatility of crop yield disturbances, or is the world finally facing a global land or water constraint? Have fertilizer and oil prices been major causes of market gyrations? How significant is the role of expansion of biofuel supply in destabilizing grain markets?

Although many of these questions cannot be answered definitively, information is available to shed considerable light on appropriate policy responses. The purpose of this paper is, given the evidence at hand, to address the merits of the types of proposals formulated in response to the sharp price spikes experienced recently, and to focus on increasing the food security of vulnerable consumers.

Fortunately, the topic is not new. Nor are the proposed policy responses; most have precursors in programs advocated or adopted after previous periods of market instability. We can draw upon experience with previous policies, and on models that show why prices in food markets can jump so abruptly, to assess the merits of recent policy proposals.
2. Price Volatility: Recent Evidence

First consider the evidence about the recent behavior of aggregate food price, which was less variable than the prices of many of its components, including food grains in particular. As demonstrated in Figure 1, in 2005 the United Nations FAO food price index showed evidence of a modestly rising trend that had moved the index less than 20% higher than the 1998–2000 average. In 2006 prices started to accelerate, and by October were on a sharp uptrend that continued until summer 2008, when the index exceeded twice its 2005 level.

By late summer, prices had fallen from their peaks. At year’s end the index had reverted to the range observed in early 2007, still much higher than in its level at the turn of the century.

Figures 2 and 3 focus on the prices of wheat and maize. Their prices followed downward trends for decades, reflecting the fact that yields have generally outpaced demand growth, contrary to Malthusian predictions of the 1960’s. Along their downward paths, prices generally fluctuate moderately within a fairly well defined range. However, episodes of steeply rising prices, followed by precipitous falls, are prominent features of the data. The price series are asymmetric: there are no equally prominent troughs in the price series to match these spikes. When price is relatively low, the probability of a sudden fall becomes negligible.

Figure 4 confirms that these features are characteristic of commodities more generally. It is interesting that the recent episode of price spikes in so many agricultural commodities, including minerals and petroleum, comes just over 30 years after the multi-commodity price turmoil of the mid-1970s. Note also that,
relative to other grain price peaks in the figure, those of the last few years, adjusted for inflation, are not particularly high.

The overall downward trend in prices can be attributed principally to the remarkable success of plant breeders and farmers in continually developing and
adopting new crop varieties offering higher yields, and to the development of cheap and plentiful supplies of such inputs complementary to the new biotechnology. Figure 5 shows the increases in world consumption of the major grains that have occurred even as the scope for expanding the area of cultivated land has diminished or disappeared in most countries. Note also the recent large surge in diversion of maize to biofuel uses.
These aggregate figures mask great regional variation in prices and consumption. But globalization of markets and reduction in shipping costs offer great opportunities for smoothing local fluctuations. Figure 6 shows rice production for China and India, both major producers and consumers, and for the world as a whole. The bottom panel shows deviations from trends. Both China and India cover so many production environments that each can, to some extent, smooth out internal regional supply and demand variations via internal trade and public reallocations. Nevertheless, pooling the entire world’s output variation and sharing it proportionately would reduce the variation of China’s and India’s shares by about 40% and 60%, respectively. For many smaller countries the effects would be far greater. These figures for wheat and maize show that the international pooling of production risks could similarly smooth national supplies. Currently, global cereal trade achieves only a fraction of these potential pooling benefits.

The trend increase in demand for grain for direct human consumption has recently been driven mainly by the increase in the global population, and the rate of increase appears to have been slowing down in recent decades. Only in poorer countries is increase in income an important driver of grain consumption per capita, which is naturally limited by the capacity of the human stomach. For grains used for animal feed, the trend increase in consumption has been greater.
because human consumption of animal products continues to rise with income long after minimum calorie requirements have been satisfied. Use of maize as an animal feed boosts maize demand far beyond what would be expected from its use as a staple food in many countries. Animal feed accounts for a smaller but still significant share of wheat production, notably in Europe. Rice is used predominantly as a food.

There is substantial agreement about the drivers of these longer run trends in grain consumption and prices. By contrast, there is a wide diversity of opinion regarding the causes of recent grain price volatility.

3. What Caused Recent Grain Price Fluctuations?

In 2008, when the rise in food prices had caught the attention of the worldwide press, observers quickly lined up a confusing array of suspects as the cause. Economists stepped in to assist in apportioning blame.

The roles played by several of these suspects are no longer controversial. These include, first, recent rapid increases in income in many countries, especially China and India, and recent neglect of crops research on a global basis. Excellent discussions of these factors are available elsewhere. I do not address them here beyond noting that they could hardly have been surprises in 2007/08, except to the extent that continuation of already established trends was unexpected. Factors such as the unprecedented extension of the severe Australian drought and exchange rate movements were much less predictable. However, as noted elsewhere, their influence was insufficient to explain price spikes of all major grains of the magnitudes seen recently. Three other market disturbances that could not have been well predicted before 2007 were global in influence, and deserve particular attention. They are the changes in biofuel policies and biofuel demand, and spikes in the prices of fertilizers and fuel, which relate directly to recent price spikes in the petroleum market.

Biofuel Demand

In addition to income and population increases in the emerging economies, another currently popular suspect for aggravating recent price increases is the conversion of oilseeds into biodiesel in Europe, the United States, and elsewhere and of maize into ethanol in the United States. In the United States in particular, the diversion of corn and soybeans to biofuel was increased substantially by the Energy Independence and Security Act of 2007. Biofuel use now approaches 30% for corn and 20% for soy, and will continue to increase under current policies which use subsidies and mandates, and protect the domestic biofuel industry.
from competition from more efficient Brazilian sugar-based ethanol production that would place less stress on short-run food supplies.

To put the magnitude of these reductions into perspective, a drought or pest infestation that reduced United States maize output by 30% in a given year would be viewed as a production catastrophe. The southern corn leaf blight infestation of 1970, which cut U.S. corn supply by only half that percentage, was viewed at the time as a very serious shock. It directed new attention to the security of the U.S. food supply in general, and in particular the danger of genetic uniformity of a staple crop. The result was a major effort to ensure the conservation of plant varieties for agriculture and diversification of genetic resources available to plant breeders. Furthermore, relative to equivalent yield drops due to transitory disease outbreaks and weather-related shocks, the mandates for diversion of United States maize for biofuel, being quasi-permanent, and indeed slated to increase, have had much more serious implications for supplies of maize for feed and food.

On the other hand, diversion of grains and oilseeds to biofuel was not a complete surprise by 2006. To the extent that existing government mandates for ethanol use were perceived as solid policy commitments, strong demand for biofuel was clearly foreseeable before prices took off. Similarly, increased demand for oilseeds for biofuel use in Europe was no short-run surprise. In both cases, however, unexpected oil price jumps must have encouraged upward revisions in expected growth of biofuel-related demand for grains and oilseeds, as did increases in biofuels mandates in the United States in 2007. As additions to biofuel feedstock demands resulting from previous policies, the diversions were too great to be made up in the short run by increased yields. They must have had large effects on the decreases in grain stocks, and the steady increases in prices, in the years immediately preceding 2007/08. The result was that food markets became much more susceptible to further shocks.

To substitute for maize diverted to ethanol, and oilseeds diverted to biodiesel, wheat and other food grains were diverted to animal feed. Consumers in some developing countries increased their demand for rice to replace the wheat used for feed. Some rice land might have been diverted to production of corn or soybeans, but this is unlikely to have had a strong impact on overall rice production; the best rice land tends to be ill-suited to corn or soy production in the temperate zones where much of the world’s corn and soybeans are grown. However, on Asian croplands where two or three crops are grown in succession each year, wheat can be substituted for rice as a dry-season irrigated crop when its relative price increases. In India, diversion of sugar land to rice in 2008 reportedly induced a sugar supply crisis in 2009.

Biofuel demands and surges in meat demand caused by rising incomes also affected food grain markets less directly, by diverting inputs including land and
fertilizer from some food crops to others used as animal feed or feedstock for biofuels.

**Prices of Fertilizers and Fuels**

Worldwide adoption of modern high-yield plant varieties and a decline in the scope for expansion of cultivated area have increased the demand for fertilizers. Prices of some fertilizers rose faster than any agricultural commodity price in the last few years, reflecting short run supply constraints, energy costs, transport costs, and a 100% export tax announced by China for fertilizers. Recently, maize farmers and ethanol producers in the United States have blamed fertilizer and oil prices for jumps in grain prices.

As Figure 7 shows, prices of major fertilizers other than DAP did not really form peaks until well into 2008, after many of that year’s crops were in the ground. It appears that grain prices associated with previous harvests generally preceded fertilizer price movements, rather than vice versa. Although there have been reports that farmers are reducing fertilizer applications, worldwide fertilizer supply is not likely to have diminished. There may of course have been reallocations to biofuel production and high-value crops. Reductions in fertilizer use should show up as yield or acreage reductions, but yields in 2008 generally appear to have been good.

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**Figure 7.** Fertilizer Price and Food Price Index

When prices are already high, subsidies have little effect on supply in the short run, but tend to divert global supplies from unsubsidized uses to less efficient subsidized uses, reducing overall production efficiency. Given a few years to invest in capacity, supplies can expand. But for fertilizers dependent on mineral deposits, increased demand might generate sustained higher prices and greater rents, without inducing much more production in the short run. Injudicious advice to further subsidize particular uses of such inelastically supplied fertilizers will, if heeded, certainly increase the profits of their producers, but is unlikely to increase the social value of agricultural production.

Crude oil, like fertilizer, is an important input—both directly and indirectly—into modern agriculture. Its price has been very high recently, but again there does not seem to have been a negative net effect on acreage or yield even in the countries that use petroleum intensively in production. Farm land prices in the United States rose dramatically as grain, fuel, and fertilizer prices were all rising, indicating that the net effect of all these changes on farmers’ profits, and their incentives to produce more grain in the short run by any means possible, was positive and large.

The dominant effect of petroleum price jumps has been to increase demand, rather than to decrease supply. Petroleum prices shift the demand for the grain indirectly, by shifting biofuel demand. This is a new phenomenon. When ethanol production exceeds mandated levels, marginal fuel price changes increase total demand for grains even as they are raising input costs. High petroleum prices might also influence politicians to increase biofuel mandates.

From this line of reasoning, one might infer that income growth and biofuel demand should have had less influence on the volatility of rice prices relative to maize and wheat prices. However, in 2008 the price spike was actually highest for rice. Does this mean that biofuel demands had no significant role in the grain price spikes after all? To answer this question we must consider two additional, interrelated factors: panic in the rice trade and inter-grain substitution by significant numbers of consumers.

Panic in Vulnerable Markets

On October 9, 2007, the Indian government, concerned about the effects of a poor domestic wheat harvest, announced a ban on exports of rice other than basmati. Large numbers of Indian consumers who eat both wheat and rice were able to substitute the rice intended for export for wheat, moderating the effects of the wheat harvest shortfall. But the ban\textsuperscript{8} meant that the supply of exports on the world market fell, and the price of rice outside of India began to rise (Figure 8, after Mitchell (2008)). The subsequent chain of events in the rice market are discussed in colorful detail by Slayton (2009).
As reports of production problems in other countries surfaced, governments of grain exporting countries were pressured by their own urban consumers to act to reduce grain prices. These pressures outweighed the interests of producers and traders in selling to the highest bidder. One by one, rice exporters imposed their own export restrictions, including, in March 2008, Vietnam, an important supplier. It also became clear that China, apparently adequately supplied, would also act to insulate itself from market turmoil, rather than make its substantial grain stocks available to the international market as supplier of last resort. Key wheat suppliers also imposed export bans or taxes.

On the other side of the market, countries that relied on imports for an important share of their food became increasingly anxious to secure foreign supplies adequate for their needs so they could satisfy politically powerful urban consumers concerned about food security. Many also reduced their tariffs on imports. Reductions in import tariffs reduce domestic prices relative to world prices, but also contribute to those world prices.

One discouraging example of inadequate international cooperation on the part of a developed country importer was the failure to negotiate the timely sale, to desperate international importers, of Japanese stocks of rice, imported in reluctant compliance with World Trade Organization mandates, and never destined for domestic consumption. The crisis in trade access and prices was resolved only

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**Figure 8.** Thai Rice Price and The Indian Export Ban

(Source: World Bank Development Prospects Group, and Mitchell (2008)).

5% broken = percentage of rice broken during transport; f.o.b. = “free on board”; Bangkok = where the rice is boarded.
after it became clear, in the Northern summer, that the current harvest was good and that, overall, 2008 rice production would be close to its trend line.

Several reviews of the above influences on the grain price volatility of the past few years have allocated percentage shares of responsibility to each. This approach makes sense if the factors have a linear cumulative effect on food price volatility. But their effect is highly nonlinear. When supplies are already tight, a small reduction can cause an unusually large price increase. It makes no sense, then, to allocate percentages of responsibility for the crisis to different causes. But at the margin, alleviation of demand pressure from non-food uses has a disproportionately large effect when supplies are short. This fact is a key to understanding recent market events and constructing appropriate policy responses.

The economics of storage activity explains the relationship between grain prices and storage, and helps in the evaluation of other factors mentioned in discussions of recent grain price behavior, including distortion of futures markets by international financial flows, and an irrational or manipulative bubble in grain prices. These issues are best discussed after a review of some features of grain storage as an economic activity.

4. The Nature of Grain Storage

To interpret the behavior of grain market prices, and identify the causes of high volatility, it is crucial to understand the relation between prices and stocks. A glance at Figure 9 reveals that the wheat price spikes in the 1970s and in 2007/08 occurred when world stock-to-use ratios were low. For the market to function effectively, a virtually irreducible minimum amount of grain must be held in the system to transport, market, and process grains. Though stocks data are notoriously imprecise, minimum working stocks are apparently close to 20% of use. Comparison of Figure 9 with Figure 2 reveals that stocks are very unresponsive to price at these minimum levels. Similarly, comparison of Figures 3 and 10 shows that spikes in corn price occurred when stock-to-use ratios were low.

A common feature of all such physical storage activity is that aggregate stocks are constrained to be non-negative. If current aggregate stocks (beyond essential working levels) are zero, it is impossible to “borrow from the future.” Another important feature of these grains (and of most minerals) is that the marginal cost of storage per period, including physical protection, insurance, and spoilage, in practice is usually modest, and the assumption of constant unit costs is a generally reasonable approximation. Increases in global grain stocks are not generally limited by storage capacity.

The fact that their supply is usually seasonal is a distinctive feature of major storable agricultural commodities. For simplicity, the discussion here considers
annual variation and assumes a fixed interest rate. Like most studies of grain storage, the focus is on market aggregates, ignoring spatial variation and product heterogeneity, as well as national policy variation regarding trade barriers, subsidies, and taxes, all of which affect the relation between reported global prices and prices faced by consumers. The observation that spikes occur only if stocks are near minimum levels reflects the constraint that intertemporal transfers via storage are unidirectional; negative storage is not feasible for the market as a whole. This reality makes modeling storage behavior interesting and challenging.

A profit is realized only if the value of the grain when released exceeds both the cost of storing it and the interest on capital. Thus the value of storage today depends on its expected value tomorrow, and so on to infinity. It seems necessary to know the answer for tomorrow before solving for the problem today. Fortunately, this problem can be solved by dynamic programming. Here the focus is on the implications of that solution for arbitrage and grain price behavior.

5. The Economics of Competitive Storage Activity

Assume that there is one crop, sown annually. The harvest in year $t$, $h_t$, is random, due to weather and other unpredictable disturbances. The effects of storage on consumption and price of grains, illustrated in Figure 11, are the
result of the horizontal addition of two demands. One, assumed to be linear in the figure, is the demand for consumption in the current period, $c_t$; the other is the demand for grain stocks in excess of essential working levels, $x_t$, carried forward for later consumption. To keep things simple, deterioration is ignored. In any period, regardless of the economic setting (monopoly, competition, state control of resource allocations) two accounting relations hold. The first defines available supply $A_t$ is the sum of the harvest and (non-negative) stocks carried in from the previous year:

$$A_t = h_t + x_{t-1}.$$ 

The second states that consumption is the difference between available supply and the stocks carried out:

$$c_t = A_t - x_t.$$ 

Assuming competitive storage, stocks $x_t$ are positive (in excess of minimal working stock levels) only if the expected returns cover costs. (Competition
between storers prevents them from making greater profits.) This means that the current price of a unit stored must be expected to rise by a sum that equals the cost of storage $k$ and the interest charge at rate $r$ on the value of the unit stored. Given available supply, $A_t$, storers carry stocks $x_t$ from year $t$ to year $t+1$ following a version of the age-old counsel to “buy low, sell high” represented by the competitive “arbitrage conditions”:

\[
\text{Price}_t + \text{Storage Cost} = \frac{1}{1+r} (\text{Expected Price}_{t+1}), \quad \text{if stocks exceed minimum levels,}
\]

\[
\text{Price}_t + \text{Storage Cost} \geq \frac{1}{1+r} (\text{Expected Price}_{t+1}), \quad \text{if stocks equal minimum levels.}^{17}
\]

As shown in Figure 11, when price is high and discretionary stocks are zero, the market demand is identical to the consumption demand. Those who consume grains such as rice, wheat, or maize as their staple foods are willing to give up other expenditures (including health and education) to continue to buy and eat their grain, so the consumption demand is very steep and unresponsive to price (“inelastic”); large changes in price are needed if consumption must adjust to the full impact of a supply shock. In 1972/73, for example, a reduction in world wheat production of less than 2% at a time when discretionary stocks were almost negligible caused the annual price to more than double, as indicated in Figure 2. Figure 11 also shows how, when stocks are clearly above minimum
working stocks, storage demand, added horizontally to consumption demand, makes market demand much more elastic (less steeply sloped) at a given price.

The responsiveness of this aggregate consumption demand to price is difficult to estimate, for several reasons. One is that, in empirical demand studies at the level of the individual consumer, it is difficult to distinguish consumption from storage (including stocks held by consumers) as prices fluctuate, and when the two get confounded the estimated response overstates the consumption response. Secondly, at the aggregate level, years with high prices and negligible discretionary stocks are too rare in samples typically available (less than one hundred years) to establish, by themselves, the steepness of the consumption demand. Estimation of the dynamic storage model offers the opportunity to use data from all available years in determining consumption demand. However, the storage model has been difficult to implement empirically. One major hurdle is, again, the lack of reliable stock (or consumption) data for global markets. (In recognition of this, grain statistics refer to “disappearance” rather than consumption.) Work that pioneered the econometric estimation of this model in the 1990s, assuming no supply response, finessed the data problem by estimating the model on prices alone.\textsuperscript{18}

Recent econometric application of a model in this tradition to prices of a set of commodities suggests that consumption demand for food responds very little to changes in the price of major commodities; the slope of the consumption demand curve for major grains may be even steeper than previously believed.\textsuperscript{19} To compensate for the low price response of consumption, more of the commodity is stored and stocks run out less frequently. The storage implied by the model smoothes prices, replicating the kind of price behavior observed for major commodities.

By acquiring stocks when consumption is rising and price is falling, storers can reduce the dispersion of price and prevent steeper price slumps. Disposal of stocks when supplies become scarcer reduces the severity of price spikes. If the supply of speculative capital is sufficient, storage can eliminate negative price spikes \textit{but can smooth positive spikes only as long as stocks are available}. When stocks run out, aggregate use must match a virtually fixed supply in the short run. Less grain goes to feed animals and the poorest consumers reduce their calorie consumption, incurring the costs of malnutrition, hunger, or even death.

Storage induces positive correlation in prices and is least effective when harvests are positively correlated; storage is ineffective in smoothing price changes caused by persistent increases in demand such as a mandated increase in biofuel production. Note also that the storage demand shown in Figure 11 would shift upwards, pulling total demand with it, if the supply variance rose or interest costs fell.
If producers can respond to incentives with a one-year lag, that response is highly stabilizing for consumption and price. Their competitive adjustments of planned production increase the effectiveness of adjustments of stocks in smoothing consumption and price. When supplies are large, for example, expected returns to production are low, so producers cut back production in response to lower returns, and hold more stocks.

6. The Counter-intuitive Effects of Price-Band Buffer Stock Programs

Many different policy interventions have been used in attempts to reduce grain price volatility or support price levels. These include controls or sanctions on private “hoarding” or “speculation,” buffer stocks, buffer funds, strategic reserves, use of options and futures, marketing boards, and price floors, all of which obviously affect storage incentives. Other measures that can also affect storage are trade barriers, export taxes, interest rate policies, and production controls.

In the past, prominent economists supported market stabilization using a price band bounded by the floor and ceiling prices to reduce the “boom and bust” gyrations typical of commodity prices (Keynes 1942, Houthakker, 1967, Newbery and Stiglitz 1981). Since 1931 there have been more than 40 international commodity agreements. The products covered include wheat, sugar, rubber, coffee, cocoa, olive oil, tea, and jute. In the 1930s international commodity agreements were explicitly designed to address the severe problems of over-supply and low prices associated with the Great Depression by restricting exports and raising prices. They had some degree of success until the over-supply problem was eliminated by the onset of the World War II. The United States from the 1930s until the 1970s operated price support schemes involving buffer stocks of major commodities and in the European Union storage-related programs to support and stabilize prices have been part of its Common Agricultural Policy.

A major element of the economic doctrine heralded as the “New International Economic Order” by the United Nations Conference on Trade and Development (UNCTAD) was negotiation of international commodity agreements (ICAs). Important programs were directed at sugar, coffee, cocoa, tin, and rubber. The first two of these, like the pre-war agreements, managed storage only indirectly via commitments to control exports, but the others involved attempts to control prices using versions of price-band schemes. When the price fell to the floor of the band, acquisitions were to be made; when the price reached the ceiling, stocks were, if available, released from the stockpile by the program’s management. A later Australian wool reserve price scheme acted more like a floor price scheme with a variable release
price and a buffer stock. Because of the distinctive nature of Australian wool, this program was effectively a global program in its effect on the market.

International agreements involving commodities, including rubber, cocoa, and tin, have often combined the floor price with a higher “ceiling” or “release” price, a plausible way to protect consumers from the most extreme effects of price spikes. Policy makers find such “price band” policies attractive because they seem simple and easy to explain. An appealing intuition is that such a program keeps the price around the middle of the price band most of the time, and affects the market mainly in unusual periods, if the band is judiciously chosen. But numerical examples made possible by advances in computing and dynamic programming, not available in the early 1970s, show that this is not true. As illustrated in Figure 12 using a simple numerical market model, for a program with a floor that is 87.5% of the mean price of $100 and a ceiling set at 112.5%, the program greatly reduces the probability of spikes above the ceiling. But the probability that the price will be at or above the ceiling is greatly increased, to 30%, and there is a probability of about 15% that the price will be at the floor. Relative

Figure 12. Price Probabilities Under a Price Floor and a Price Band
to a free market with storage, there is a much lower probability that price will be located between the mid-point of the band and the top.

Most of the time, the market appears to be “challenging” either the floor or the release price. The price ceiling discourages production and storage and increases volatility of the price as the latter approaches the ceiling. Paradoxically, the price is much more likely to be near the center of the band under the free market, or where program stocks are made available for release to private storers and consumers at the floor price.

Another serious consideration is budget cost. When a program chooses a price floor $p^F$ that is no higher than the free-market mean (adjusted for a perfectly estimated trend if necessary) or a price band where the mean of the floor and ceiling price equals the free-market mean, the program has frequently been assumed by economists (see, for example, Newbery and Stiglitz 1981) to be “self-liquidating”—that is, financially sustainable, based on the fact that expected net balances should equal zero and the intuition that the summed funds from purchases and sales after several years of operation should be close to their initial values. But this intuition is wide of the mark even for a simple floor price scheme in a market with no underlying trend.23

The fund may in the short run accumulate great profits, appearing to affirm the manager’s skill and to belie the skepticism of “theoretical” economists, inducing pressure to raise the price floor. Such pressures can be very difficult to resist.24 Even if the manager can commit to the original rules, any given operating reserve will be depleted in finite time.

In practice, postwar experience has affirmed that the “finite time” within which such programs fail is disconcertingly short, often less than a decade or two. Recent failures in programs for tin and wool, among others, have shown that the largest price effect of these interventions can be the severe price collapse that accompanies their inevitable failure.25

When such price support programs do fail, there is generally a public consensus that the intervention price was wrongly set; management is often blamed for faulty trend forecasting. There is scant recognition that failure is inevitable at any relevant intervention price even if the fundamentals are stationary. Higher floor prices merely advance the time of reckoning. Price band programs tend to fail sooner because they tend to accumulate stocks at a faster rate.

The attraction of price bands might well be at least in part due to the failure to appreciate the potential of competitive storage. To illustrate the latter, it is necessary to use a numerical dynamic model of competitive storage. Figure 13 illustrates three probability densities for prices conditional on current prices at, respectively, 74%, 94%, and 114% of the mean generated by a numerical model of competitive storage. In this example, if price is 94% of the mean, there is virtually no chance it will be below 70% of the mean the next year. If, after a string of
good harvests, the price does eventually fall to 70% of the mean, there is virtually no chance it will fall below 60% (or rise above 110%) the following year. Note also that if the price is 114% of the mean the figure indicates a much larger chance of a lower price than a higher price the following year. There is a modest right tail indicating the probability of a price at least 14% above the mean but the model is acting much like an imperfectly effective price-band program with a floor around 65% and a ceiling around 114% of the mean price.

In sum, much of the stabilizing benefits of a price-band scheme are furnished by competitive private storage in a free market in which there is no fear of punitive measures against “hoarding” or other perceived offenses. Price-band schemes in theory are bound to fail if the bands are not adjusted to reduce losses. In practice, failure comes fairly quickly. If, on the other hand, bands are adjusted to reduce accumulation of losses, the program tends to mimic what the free market can provide. Price-band schemes are unsustainable and expensive, in theory and in practice, and can be hugely destabilizing when they fail.

7. Public Policy for Grain Supply and Food Security

Since ancient times, national leaders have recognized a responsibility to ensure adequate domestic availability of staple foods. For example, the Ch’ing Dynasty in
China maintained a nationwide granary system with responsibilities that included moderation of seasonal fluctuations and famine relief.

Intervention in markets for staple foods is still prevalent, even in modern capitalist economies. Why is this so? Surely an undistorted free market could equalize the marginal value of a given grain supply across alternate uses, including placement in storage?

In a free market, only those who have the necessary resources or “entitlements” can acquire food. The needs of the destitute may not affect prices at all. Whether or not governments have any sympathy for the plight of the poor, only the most totalitarian are able to ignore pressures from consumers mobilized by concerns for their own consumption needs. In response to this temporarily powerful constituency, governments often force traders who have accumulated grain to surrender those stocks to the government or directly to consumers, often without compensation. Such so-called hoarders are typically vilified, and sometimes also punished or even killed. In such emergencies, the argument that the “hoarders” might be the sole source of supply if the next crop fails gets scant consideration.27

Anticipation of such treatment understandably discourages private storage for distribution at a high price in time of need. Even if a government commits not to confiscate stocks (or otherwise penalize hoarders) in emergencies, a commitment against all intervention that would discourage speculation is not credible. Hence governments often choose to supplement private storage with publicly acquired stocks or storage subsidies. (Even if the government manages all market stocks, it is difficult to prevent consumers from storing some domestic supplies.) When public stocks are released to consumers (other than those with no money at all for food) they will, to some extent, have a negative effect on prices. Anticipation of this price effect reduces private storage incentives below those offered by a free market. Hence it is natural to expect that governments will intervene actively when supplies are plentiful to increase grain stocks and thereby help ensure supplies for the needy and/or stabilize the market.28

Before assessing specific grain market interventions, it is useful to be aware of the following facts:

1. Any activity or policy that does not change consumption in a market does not affect prices in that market. On the other hand, if a policy decreases price, it increases consumption and decreases stocks. If planned production is responsive, it also decreases when the price drops, unless the spot price is so high that there are currently no discretionary stocks.

2. If they fail to address the fundamental source of disturbance (for example, disease, war, arbitrary policy initiatives or weather), “stabilization” policies must actually destabilize some key variables (stocks or public budgets, for example) as they stabilize others (such as price).
(3) There is no evidence that any chosen group of experts, no matter how well qualified and motivated, can reliably determine when a competitive market is acting in a way not justified by fundamentals. The general proposition that designated experts can outperform the market in forecasting or trading might have been plausible in the time of Keynes, but a large body of empirical evidence to the contrary has accumulated in the intervening decades. The best-informed international organizations concerned with food markets for the poor (including the World Bank) wisely make no claims of superior forecasting capacity.

(4) In any intervention, net efficiency gains to society as a whole are typically dwarfed by redistribution of gains and losses between producers and consumers. Those who most enthusiastically and effectively support storage interventions naturally tend to be the ones who expect to gain from those policies. To comprehend these distributional effects, it is necessary to recognize the dynamic nature of the problem and the importance of private responses to public actions.

With the above points in mind, let us consider several recently discussed policy initiatives:

**A Proposed International Coordinated Global Food Reserve**

The recently evident failure by many grain exporters (especially in the rice market) to commit to offer uninterrupted market access to their supplies has highlighted the desirability of commitment-reinforcing mechanisms for international grain market participants. One such mechanism, an international coordinated global food reserve, has recently been proposed. The rationale for this reserve is to reassure importers that they could rely on exporters to supply them in time of need. The proposal is sketched as an agreement by members of a “club” that would include members of the G8 + 5 plus major grain exporters such as Argentina, Thailand, and Vietnam. Members would commit to holding specified amounts of public grain reserves in addition to reserves held by the private sector. The public stores would be used for emergency aid as directed by the World Food Programme.

**A Proposed Global Virtual Reserve**

A related proposal is for a global “virtual reserve.” Nations that are members of the “club” would commit funds amounting to US$12–20B to be provided, if necessary, to the high-level technical commission for operations in the futures markets. One version of the proposed intervention characterizes it as a dynamic price-band system operated by a “global intelligence unit” that apparently is assumed to have superior forecasting ability, and can reliably detect when the market price has departed from levels supported by fundamentals.
By operating via long futures positions, the scheme would aim to induce a buffer stock indirectly, by raising future prices and thereby inducing increased private stockholding. This virtual scheme, if large enough to move markets (and if allowed under the rules of relevant commodity markets), would require ready access to large and in fact indeterminate amounts of margin financing, and be subject to manipulation by traders. This initiative ignores a major achievement of empirical econometrics in economics and finance in the decades since UNCTAD advocated buffer stock programs as part of its New Economic Order, namely the accumulation of evidence against the proposition that a group of “experts” can reliably outguess the market. If, as we have every reason to believe, its global intelligence unit does not in fact have superior forecasting ability than the market as a whole, it will lose money on average, and will eventually exhaust its budget, like schemes with similar ambitions dating back many years. One example, reviewed in Peck (1976), is the Federal Farm Board’s intervention in the United States’ cotton and wheat markets using futures contracts to try to stabilize prices in the face of a bear market during the Great Depression. This stabilized American wheat prices for a year or so before essentially owning the United States’ wheat stocks and losing $188 million—a great deal of money in the 1930s—and being disbanded. Regional supplies were severely distorted even within the United Stated market, creating shortages in some localities and gluts in others, an unanticipated collateral effect of relevance to modern proposals for price interventions. For a multilateral program, another major challenge for such a commitment-reinforcing program is to ensure commitment by the participants themselves to honor their obligations when markets are under stress.

In another interpretation reflecting written sketches by von Braun and Torero (2009) and Robles, Torero, and von Braun (2009), the operator would not attempt to operate a price band, but would stand ready to take naked short positions (not backed by stocks or prospective harvests) when a disequilibrium price surge is reliably detected. The idea appears to be that this action would convince speculators to sell their discretionary stocks, and thus reduce prices. Apart from the problematic and unverified assumption of superior information, one must recall that, as noted above, all recent grain price spikes have occurred when there were almost no stocks available for speculators to have held and later released.

Futures Market Regulation

In any grain price crisis, futures and options traders get blamed sooner or later. This happened in the United States, for example, in the last century when many forms of futures and options trading were banned and it is happening again now.31 This time, the critiques come with novel twists.
The major criticism focuses on the entry of new money from (1) index funds holding persistent long positions (contracts to purchase grain in the future at a set price) and managing those positions by rolling the hedges over to later maturities or increasing or decreasing their positions to maintain portfolio allocation shares, and (2) speculative investors such as hedge funds. The argument is that these long positions have added buying pressure, raising prices for the physical commodity above the levels justified by supply and demand.

For United States futures markets, the facts tend to contradict the assumptions underlying this critique. First, for soybeans and maize in particular, short-hedging by producers, merchants, and processors grew more from 2006 to 2008 than did long speculation. For wheat, the increase in long speculation was greater but the relative magnitudes stayed within normal ranges. Second, the commodities for which index investment grew most over the two years saw no significant price increases. Third, commodities neglected by index funds (such as rough rice and fluid milk) experienced large price increases, as did commodities with no futures markets at all (apples, edible beans). Fourth, index funds, if operating as advertised, rebalance as grain prices rise, reducing long positions to maintain portfolio shares, and thus stabilizing prices somewhat like a more flexible variant of a price-band policy. Fifth, empirical work has shown no significant evidence that position changes by speculators help forecast price changes in these markets.

Finally, if long futures market positions exacerbated price spikes 2007/08 they must have reduced consumption and increased commodity stocks. But stocks were around minimal feasible levels. To the extent that speculators might have influenced the market by increasing stocks in previous years, their unwinding of those positions should have increased consumption and moderated price, hardly undesirable effects.

Policies to Prevent Irrational or Manipulative Bubbles

The reality that overall grain availability increased prompted a second and quite different rationalization of the crisis in the grain markets: there were irrational or manipulative bubbles attributable to “greedy” speculators that burst in the spring and summer of 2008. In 2007, one story goes, prices got out of line in the grain markets and supplies were withheld in anticipation of greater profits later. The sharp reversals of grain price trends in different months of 2008 are viewed as confirmation of this interpretation: the “bubbles” proved unsustainable, as bubbles always are, and burst. Given the recent history of financial markets, an explanation dependent on greed and irrationality is both plausible and appealing.

Unfortunately, recent research on models of commodity markets like the one represented in Figure 12 but with slightly different, though hardly unconventional, demand behavior has shown that irrational bubbles are difficult if not
impossible to distinguish from rational investment behavior by nonmanipulative market participants, just as greedy investors are appear to be indistinguishable \textit{ex-ante} from regular profit maximizers.

There is another reason to discount the need to prevent bubbles. If a bubble occurred in a grain market in 2007/08, to affect price it must have increased stocks. But, as previously noted, stocks were at or close to minimum levels. Where were the increased stocks to be found as prices rose to their peaks? Moreover, had such stocks existed, would it have been prudent, \textit{ex-ante}, to force the release of scarce stocks if there were no guarantee that the next harvest would be better?

\textit{Controls on the Investment of Excess Global Liquidity}

A related set of arguments points to the entry of holders of new and cheap capital into commodity futures markets in the past few years as a key cause of grain price spikes. One part of the argument has some plausibility and is favored by respected researchers in international finance. A brief sketch goes as follows. A large pool of global capital accumulated largely in China was invested in the United States housing market until that market collapsed. Hoards of these global dollars, seeking new targets, were dumped into the commodity markets through hedge funds and other investment vehicles. These new dollars caused commodity prices to soar.35

All but the last sentence is plausible. The real cost of capital to major financial and commodity markets was low until the United States financial sector descended into disarray and international dollar surpluses were a part of this phenomenon. As previously noted, lower interest rates tend to be associated with higher stocks, higher current prices, and lower futures prices. But the facts regarding key agricultural commodity market behavior just quoted fail to imply any causal relation between the cash inflow and commodity price spikes. This is not surprising. No one has demonstrated that this cash increased grain stocks when, as previously noted, stocks were around minimal feasible levels for normal market operations. As previously noted, if the cash inflow did not increase stocks, it cannot have reduced consumption or raised the market price in the short run. If it did increase stocks earlier, their release before the price spiked must have moderated the price increase and smoothed consumption.

8. Recent grain price spikes: A reappraisal

If international income growth, population growth, futures market speculation, irrational bubbles and global financial flows do not explain the recent grain price spikes, what does? Why were they so large? Were they caused by the oil price
surge shown in Figure 4? Were they irrational bubbles, unrelated to fundamentals, after all?

An important part of the answer is that the spikes, appropriately deflated, were not unusually large. Look again at Figures 2 and 3. There were comparable spikes around 1996—smaller for wheat, larger for maize. Another glance at Figure 4 shows that those spikes were clearly unrelated to oil prices, which were stable around that time. They could hardly have been caused by index fund investment—one of the two major indexes was not even in existence then.

A more promising line of investigation is suggested by Figure 14, which shows world stock-to-use ratios for the sum of the three major grains (corn, wheat, and rice).\(^{36}\) Around 1996, the world aggregate stock-to-use ratio was much higher than recently. But the world figure was distorted by the huge holdings of China, whose exports were negligible in that period. If China’s effect is removed, the ratio around 1996/97 looks as tight as observed in 2007/08. The lack of stocks in both episodes left the market susceptible to large price spikes from small supply disturbances. One possible objection to this assertion is that the ratio was about as tight around 2002-2004 and yet the price changes observed then were much smaller. But in that period, in contrast to the other episodes, China made substantial exports of maize and rice, increasing available supplies in the global grain market. Thus the recent history of grain markets supports two conclusions. First, the price spikes of 2008 are not as unusual as many discussions imply. Second,

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**Figure 14.** World Stock-to-Use Ratios for the Sum of the Three Major Grains (Corn, Wheat, and Rice)

(Source: USDA Foreign Agricultural Service–Production Supply and Distribution Online).
the balance between consumption, available supply, and stocks seems to be as relevant for our understanding of these markets as it was decades ago.

9. Policy Responses to Ensure Adequate Consumption

The evidence reviewed above points to the key role of stock levels in recent market volatility. The following policy options address this age-old problem in several ways, with the general objective of mitigating the effects of volatility on the most vulnerable consumers. Some are variations of programs that have been implemented in the past. Others informed by recent experience, or motivated by the new challenge posed by use of agricultural resources for liquid fuel production, are more novel and less time-tested, but well worth considering.

Emergency Food Reserves to Stabilize Consumption of Vulnerable Groups

If such a reserve is successfully targeted at a small part of the aggregate consumer market, it should not have a major effect on prices in the broader market. Operation of disaster relief programs typically requires reserves to be on hand to ensure a smooth and timely response to food supply emergencies and related humanitarian disasters. One would anticipate that this type of stock would be used for local and regional food shortages, often in landlocked countries or failed states. Such shortages are usually unrelated to global market conditions, and the stock is of smaller magnitude than needed for a global price stabilization scheme, so the exporter commitment problem previously discussed is less serious, though still a serious issue. Recent difficulties involving lags in food aid responses and mismatches between years when aid is plentiful and years when it is needed might be alleviated by such a reserve. On the other hand, care must be taken to minimize disincentives caused by the price-depressing effects of food distribution for the local farmers and merchants who are the first line of defense against famine for such countries.

The reserve could be useful in improving the speed and flexibility of short-run responses to local food crises. But its operation presents many challenges familiar to administrators of aid programs. For example, measures should be taken to ensure that transport will be available for delivering this aid, especially for landlocked countries such as those in Africa that have recently encountered food crises. It seems likely that direct assistance to the neediest, where feasible, would be more effective than attempting to reduce prices by supplying extra grain to regular food markets. Public employment programs for those needy who are able to work have been successful in cases where it has been possible to keep the reward for work low enough to be unattractive to those with other employment
alternatives. A modest emergency reserve of this type could be crucial for improving responses to local humanitarian crises. However, its impact would be negligible on the global market volatility that is the focus of this paper.

**National Strategic Reserves to Stabilize Consumption**

Such reserves are designed to ensure adequate national consumption in those (hopefully infrequent) occasions when a country finds itself cut off from its regular access to food imports. Thus they will affect national prices in emergencies, but should not eliminate incentives for private stockholding. One reason that grain prices have not declined further from recent peaks is that many countries are rebuilding or expanding their grain reserves in reaction to the export bans and export taxes observed recently. Such actions appear almost inevitable at the national level given the inability of exporters to commit to being reliable suppliers in emergencies. According to a recent report, the United Arab Emirates, presumably capable of offering a logical food-for-oil deal, were unable to obtain blanket assurances from Pakistan that grain produced from the Emirates’ planned agricultural projects in that country would not be subject to export controls. Futures contracts eliminate counterparty risk but can expose countries to location-basis risk and sudden large margin calls. Further, a futures market might be shut down or exports banned; both actions were taken in India in 2007 at a time when the situation in its grain markets fell far short of emergency conditions.

A key question is how large the reserve should be. The answer must depend on the facts of each case, including the diversity of food supplies, dependability of traditional suppliers, and cost of the program. Such stocks tie up capital for the substantial intervals between releases and can be expensive to maintain, especially in humid tropical countries. Their efficient management also uses scarce human capital and temptations for corruption can easily arise.

If the public stock’s management can commit to hold the stocks for release only in circumstances in which private stocks would be exhausted, the disincentives to storage by the private market can be reduced. For a landlocked country, this type of emergency situation might be the second year of a severe drought. For an importer, it might be the second year of a global shortage. In such real emergencies, releases of stocks via direct distribution outside the market can be targeted to ensure that all consumers receive what is minimally needed, as previously discussed for the case of the small emergency reserve. A release policy designed to operate via its effect on the general market price is likely to be more costly and less effectively targeted to those in need.

Thus the national storage activity discussed here is appropriately directed at a stockpile of a certain size deemed appropriate to meet security goals rather than aimed at modification of the behavior of prices. In contrast, many international
commodity agreements and some programs proposed recently are targeted at market-wide price behavior rather than targeted consumption goals.\textsuperscript{44}

Besides measures affecting storage activity directly, other policies might be considered to reduce market volatility and/or increase market access. Some of these have substantial merit; others do not. We now turn to several of these, starting with the more promising.

\textit{Improvements in Availability of Critical Information}

One striking feature of recent chaos in grain markets is the paucity of timely data on available stocks in each country and particularly in Asia. Earlier and more accurate data can reduce volatility, improve planning, and encourage international confidence and cooperation. Until now, key national participants have treated their stock data as a national secret and a source of commercial advantage. Policies that facilitate communications between private traders have great potential for preventing famine in isolated markets. Fortunately, improvements in Global Information Systems are improving global access to information on weather, production, and stocks without the need for international collaboration on data sharing. Aker (2008) has shown that spatial price and supply variation in Niger during the recent famine was moderated by the adoption of cell phones by key traders, as they became available.

\textit{Commitments to Refrain From Using Export Restrictions}

Recent experience in the rice market has demonstrated the hazards associated with reliance on imports to satisfy needs for a staple commodity. Exporters and importers have a joint interest in keeping trade open when prices are high so they can together reap the full benefits of the smoothing role of trade, which can exceed what can be achieved via storage. But commitments to do so are difficult to achieve and can easily collapse due to pressure from politically powerful urban consumers. One useful policy change to improve the commitment capacity of exporters would be a reform of WTO disciplines on export bans and export taxes consistent with existing rules against import tariffs and quotas. Whether such a reform is feasible is a question I leave for others to decide.

\textit{Creation of Options to Divert Grains From Biofuel and Feed Uses in Emergencies}

Modern food markets are, in an important sense, more inherently stable than their predecessors. Now, a significant portion of the domestic supply food grains and oilseeds is used for biofuel in many countries, and for large-scale animal feeding in many more. The increasing non-food uses for grains increases the
pressure on food supplies, but it also offers a new source of emergency supplies in food crises. In such circumstances, it should be possible to ensure diversion of some feed grains and oilseeds from use as animal feed or biofuels feedstocks to domestic use as food distributed to vulnerable consumers, without undue hardship to the generally more prosperous consumers of substantial quantities of energy or meat. (Commitments for international diversion are much more problematic.) Similar contracts have been used, for example, to ensure secure urban water supplies in the United States by diversion from irrigation during droughts, including diversion of irrigation water to urban consumption. (See O'Donnell and Colby 2009 for a guide to such contracts, and Hansen and others 2008 for other references.) On a different time scale, interruptible electric power contracts are commonly used for industrial customers willing to relinquish claims on electricity when net supply is low.

The food supply authority could purchase call options on grain from biofuel producers, most likely directly, with performance guarantees, as trade volume is unlikely to support an organized exchange. Diversion would be triggered by specified indicators of food shortages, and the biofuels supplier or animal feeder would commit to make a corresponding reduction in output (rather than substitute other food grain as feedstock). Delivery specifications could be designed to ensure the grain will get to where it is needed in a market emergency. All parties can gain from implementing such contracts.

If biofuels mandates inhibit such diversion, they should be altered to allow for use of such options. Better yet, biofuels mandates should be made conditional on food prices or availability. But the conditional mandates are not sufficient to protect consumers. If petroleum prices soar, biofuel demands could trump those of poor food consumers. The proposed options would protect consumers in such circumstances.

If biofuel feedstocks are sourced from permanent stands of miscanthus or other perennial grasses with low feed value, rather than from annual grains, this potential flexibility could be lost. If biofuel conversion of such inedible crops becomes more efficient, producers may well be tempted to increase the area planted to them. In that case, the threat of biofuels to food supply security could become much more serious than it is at present, and diversion of animal feed would become more important.

10. Conclusions

The storability of grains causes the price response to a change in supply to vary with the level of available supply. The major grains—wheat, rice, and maize—are highly substitutable in the global market for calories. When their aggregate
supply is high, a modest reduction can be tolerated with a moderate increase in price by drawing on discretionary stocks. But when stocks decline to a minimum feasible level, similar supply reduction can cause a price spike. In a free market, poor consumers with little wealth may be forced by high prices to spend much of what resources they have on food and reduce consumption at great personal cost. Others reduce consumption very little even when prices soar.

In 2007/08 the aggregate stocks of major grains carried over from the previous year were at minimal levels due largely to substantial mandated diversions of grain and oilseeds for biofuel and strong and sustained increases in income in China and India. Lack of stocks rendered the markets vulnerable to unpredictable disturbances such as regional weather problems, the further boost to biofuel demand from the oil price spike in 2007/08, and the unprecedented extension of the long Australian drought. However, supplies were sufficient to meet food demands without jumps in price, had exporters not panicked, leading to a cascade of export bans and taxes that cut off importers from their usual suppliers.

If in future food shortages more serious supply problems arise, there is little doubt that export bans will recur. Governments that recognize an obligation to protect poor consumers or are sensitive to pressure from consumers will intervene. Exports will be taxed, cut, or banned, distorting private storage incentives and cutting off importers’ access to supplies. Given these realities, there is a case for public interventions when supplies are more plentiful in anticipation of future crises.

Deflated prices of food grains follow long-run downward trends interspersed by episodes of steep price increases immediately followed by even more precipitous price falls. Relative to other episodes of grain price spikes, volatility in the real grain price the past few years has not been particularly high. There is no evidence of a change in the global grain price regime.

Their experience in the grain markets in the past few years has encouraged many governments to build or expand national grain reserves. If such reserves are aimed at ensuring minimal levels of consumption, they should be designed to meet the needs of vulnerable consumers by nonmarket distribution in emergencies. Decisions about their size should reflect both the advantages of secure supplies and the substantial costs of acquisition, storage, and administration.

The recent food price spikes have led to several proposals for international intervention in commodity markets. One suggests that creation of a small emergency reserve to respond quickly to regional emergencies would help speed up responses by international organizations in aiding groups in distress. The free market cannot be relied upon to service this need, for such groups lack the resources to bid for the food they require. Since regional emergencies often involve landlocked nations, contingent transport contracts may be useful to ensure adequate and timely distribution of stored grain.
A large international grain reserve, held at optimal locations and controlled jointly by national governments to mitigate global food supply crises could economize on stocks and storage costs in providing a globally adequate amount of storage and help maintain the valuable stabilizing role of free international trade in grains during emergencies. Unfortunately, such an ambitious scheme appears to be infeasible without improved means of guaranteeing continued international collaboration by the participants during food emergencies. Stronger WTO disciplines on export tariffs and adoption of disciplines on export bans are would increase incentives for collaboration, but are unlikely to be persuasive in serious food price crises.

Other recent responses to the events of the last few years include proposals for a combination of international physical reserves provided by members of a group of national participants and “virtual” reserves to control speculative price behavior in grain markets. In at least one version, the interventions would be naked speculative short positions taken when a global intelligence unit using special knowledge unavailable to the market decides, using criteria not identified, that prices do not reflect “fundamentals.” Similar proposals made many years ago were easier to take seriously. In the last half century, a large body of work including theoretical and empirical analyses has shown how difficult it is, even for top experts, to be sure that markets are out of equilibrium and that proposed price interventions will do more good than harm. Naked short speculation to stabilize prices is very risky and indeed could quickly lose vast sums of money, especially if positive initial results increase the confidence of management, encouraging decisions that lead to greater financial exposure.

Use of price-band rules to operate international or domestic market stabilization schemes is less simple than often assumed and less effective in ensuring food security for those most at risk. The price tends to hover at or near the upper or lower band, private storage is reduced or eliminated, and production is discouraged just when it is most needed. Theory predicts, and experience confirms, that these programs inevitably fail even if there is no underlying trend in price.

The recent history of the markets for major grains highlights the need for greater caution in adopting policies that subsidize or, worse, mandate further diversion of grains or grain-producing land to biofuel. Abrupt increases in diversion to biofuels can induce serious price spikes when stocks are low, threatening the security of grain for consumption by the world’s most vulnerable consumers, and continued diversions will lead to increases in the levels of food prices; poor consumer will pay a price for biofuels consumption by others.

On the other hand, the reality that substantial quantities of grains and oilseeds will continue in the near future to be converted into biofuel or animal feed in many countries suggests a new strategy to ensure that the most vulnerable consumers have access to sufficient food (as distinct from the goal of stabilizing
market price). Governments of nations with substantial domestic biofuels production or livestock feeding industries should seriously consider the purchase of diversion options from producers of biofuels or meat products, much like dry year options in water markets. These option contracts would give government the right but not the obligation to acquire, in serious pre-specified food supply emergencies, domestic grains or oilseeds that would otherwise be allocated to biofuel production or animal feed. These grains could then be made available as food for consumers (or substituted for other types of feed grains more attractive to human consumers). All parties could gain from such diversion options, which could be written as contracts with specific biofuels producers; they are not necessarily dependent on the existence of a commodity exchange.

Notes

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1. See Slayton (2009) for a colorful account of the rice market in this period.
3. In June 2009, wheat prices surged to their highest levels since October 2008.
4. Although we must focus on aggregate numbers here, it is important that they mask a tremendous amount of variation between countries, due to trade barriers, exchange rate movements, domestic price and tax policies, and transport costs. As trade barriers, tariffs and transport costs have changed abruptly, the scope of various international markets has also been redefined. Furthermore, in large or landlocked countries international prices often face widely varying prices; for many consumers, international prices and policies discussed here have little relevance, as noted below.
6. Though Brazil is a major biofuel producer (using sugar cane), its production reportedly has not diverted large acreages from grain production.
8. There have been conflicting reports on the extent to which the announced ban actually reduced the size of Indian exports. But here is no doubt that the ban created great anxiety among importers. As noted, lack of reliable information on quantities is a bane of global grain markets.
10. Timmer (2008). I have no information that Japan has actually sold these stocks.
11. Near minimum stock levels, small additional fractions of stocks are placed on the market only when the incentive is very high. These stocks may be in relatively inaccessible locations, given current transport costs, or perform valuable roles in keeping the system operating efficiently, such as avoiding the use of half-empty railcars. The small feasible changes in these stocks are ignored here; they have negligible effects on food supply or price volatility. For model of the supply of these stocks, see Bobenrieth, Bobenrieth and Wright (2004).
12. Paul (1970). Deterioration is not important for grains stored in appropriate environments but can be serious in hot and humid environments.

13. In contrast, storage of extra water in a reservoir may incur virtually no extra cost until it reaches full capacity, beyond which extra storage is infeasible in the short run. Above-ground storage of petroleum is similarly limited.

14. Transaction costs associated with adding or removing stocks are assumed to be negligible.

15. Discounting by the cost of capital also makes the timing of benefits and costs to producers, traders and consumers important in determining who gains and who loses from policies affecting storage activity. See Wright and Williams (1984).

16. The first paper to pose the solution to this problem in a modern analytical fashion is Williams (1936). The first satisfactory solution following the approach proposed by Williams appeared more than two decades later in the pioneering dynamic model of Gustafson (1958). A solution method for storage models with responsive supply and rational expectations was first presented in Wright and Williams (1984). See also Williams and Wright (1991, chapter 3).

17. That is, the arbitrage equations for risk–neutral competitive storers who maximize expected profits can be written as

\[
P(A_t - x_t) + k = \frac{1}{(1 + r)} E_t[P(x_t + \tilde{h}_{t+1} - \tilde{x}_{t+1})], \quad \text{if } x_t > 0;
\]

\[
P(A_t - x_t) + k \geq \frac{1}{(1 + r)} E_t[P(x_t + \tilde{h}_{t+1} - \tilde{x}_{t+1})], \quad \text{if } x_t = 0,
\]

where \( k \) is marginal physical storage cost, \( E_t \) denotes the expectation conditional on information available in year \( t \) and \( \tilde{h}_{t+1} \) and \( \tilde{x}_{t+1} \) are random variables.

18. Deaton and Laroque (1992, 1995, 1996), Chambers and Bailey; Miranda and Rui. The conclusion they draw from their estimation using pseudo maximum likelihood is that the storage model cannot reproduce the serial correlation observed in prices of major commodities.

19. Cafiero and others (2011) show that Deaton and Laroque’s negative conclusion regarding the ability of their model to fit the data is due to numerical inaccuracy in the implementation of the estimation model. Bobenrieth, Bobenrieth, and Wright (2010b) present a maximum likelihood estimator for the storage model and apply it to the world sugar market.


21. There are important interactions between band width, private storage within the band, the supply response, the expected rate of accumulation of losses, and the maximum level of stocks. See Williams and Wright (1991, chapter 14).

22. See Williams and Wright 1991, p. 404 for a similar figure. Supply elasticity is one 1.0 with a one-year lag, consumption demand is linear with price elasticity at the mean equal to -0.2, interest rate is 5% and coefficient of variation of harvest is 0.1.

23. To see this, consider the simple case in which demand is linear and planned production is constant so the mean price is exogenous. Assume further that the harvest has a symmetric stationary two-point distribution, that there is no private storage, and that \( p_p \) is set at the mean price—the price when consumption equals mean production. Imagine a “buffer fund” scheme whereby the government pays \( p_p \) for each unit sold at each time \( t \). Negative payments are receipts by the government. The fund’s monetary balance, \( B_t \), with initial value \( B_0 \), follows a random walk. Given an infinite horizon, the balance passes any finite negative bound in finite time and the probability that it is zero at any future date is the same as the probability that it is never zero before that date and quickly becomes negligible (see Feller [1967, lemma 1, p. 76]). Similarly, a price floor backed by a buffer stock generates a fund balance that hits zero with probability one in finite time (that is, “infinitely often”). If a price ceiling is added, the expected time to a zero balance is shorter.
24. The history of the Australian reserve price scheme for wool (a more complex version of a floor price scheme) is a salutary example where short-run success boosted the confidence of management in its own judgment, leading to decisions that hastened the later catastrophic failure.


26. See Figure 6.8 in Williams and Wright (1991), p. 171. Consumption demand is linear with price elasticity at the mean -0.2, supply elasticity is zero, coefficient of variation of harvest is 0.1, and interest rate is 5 percent.

27. In the United States, long-run speculators, whose futures positions provide the incentive for storage by short-hedgers, have recently endured a great deal of negative attention, regardless of a lack of evidence of excessive stocks.

28. For more extensive discussions of the rationale for public intervention in storage markets, see Wright and Williams (1982b) and Williams and Wright (1991, chapter 15).

29. von Braun and others (February 2009).

30. von Braun and others (March 2009), p. 3.

31. See for example United States Senate Subcommittee on Investigations, Excessive Speculation in the Wheat Market, June 24, 2009, which conflates a real and persistent issue, the failure of convergence of spot and futures prices at delivery, with broader conclusions regarding the role of speculation in market volatility.

32. See Irwin and others (2009).

33. See Verleger (2009) for related findings for the market for crude oil.

34. See the Granger causality tests in Sanders, Irwin, and Merrin (2008).

35. See Caballero and others (2008) for a version of this argument focused principally on the oil market.

36. This figure and the associated argument draw on the work of Dawe (2009).

37. An example of such a reserve forms the first part of a recent three-point proposal by von Braun and others (2009). It sketches an outline of a small “independent emergency reserve” of about 5% of the current annual food aid flow of 6.7 wheat-equivalent metric tons. This would be a decentralized reserve managed by the United Nations World Food Program and held in existing national storage facilities at strategic locations with essentially a call option on the grain deposits at pre-crisis prices.

38. Even if we ignore this difficult issue, optimization of the details of location and operation presents a challenging spatial-temporal problem that merits further attention. See Brennan, Williams, and Wright (1997) for a spatial-temporal model of an exporting region that gives some hint of the issues involved in modeling imports of food aid for a geographically dispersed population.

39. See, for example, Subbarao (2003).

40. The United States Strategic Petroleum Reserve has a similar purpose. Even though its interventions are infrequent, its operation does appear to have reduced private stocks by about half the amount stored in the reserve, consistent with the ex-ante analysis of Wright and Williams (1982b).

41. Recent reports indicate that Saudi Arabia, Egypt, Iran, China, Russia, Jordan, Mozambique, Morocco, and Malawi are among the countries placing grain in national reserves (Marc Sadler, personal communication, April 30, 2009).


43. Stocks would be “rolled over” with no net release as frequently as needed to maintain quality.

44. One reason might be that the (generally urban) consumers who most influence the government often are not those most in need.

_____. 2009. What’s Driving Food Prices? March 2009 Update. The Farm Foundation, Oak Brook, IL.


Wright


