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Abstract: In times of highly volatile commodity markets, governments often try to protect their populations from rapidly-rising food prices, which can be particularly harsh for the poor. A potential solution for food-deficit countries is to hold strategic reserves that are called on when international prices spike. But how large should strategic stockpiles be and what rules should govern their release? In this paper, we develop a dynamic competitive storage model for wheat in the Middle East and North Africa (MENA) region, where imported wheat dominates the average diet. We analyze a strategy that sets aside wheat stockpiles, which can be used to keep domestic prices below a targeted price. Our analysis shows that if the target price is set high and reserves are adequate, the strategy can be effective and robust. Contrary to most interventions, strategic storage policies are counter-cyclical and, when the importing region is sufficiently large, a regional policy can smooth global prices. Simulations indicate this is the case for the MENA region. Nevertheless, the policy is more costly than a pro-cyclical policy similar to food stamps that uses targeted transfers to directly offset high prices with a subsidy.

Keywords: food security, Middle East and North Africa, price volatility, storage, strategic reserve, wheat.

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High and volatile food prices, and their consequences for the poor, have revived concerns about food security and reinvigorated the debate about the role of strategic storage. For the second time in three years, food prices on international markets spiked in 2011, driven in part by rising wheat prices. For the first time in more than a decade, the real price of US wheat exports (adjusted to 2000 prices) breached the $200/ton threshold in July 2007 on its way to a high of $352/ton in March 2008. International food prices fell sharply toward the close of 2008, wheat prices among them. By June 2010, wheat prices fell to $131 per ton, only to double within the year. Estimates suggest that the 2011 food price spike pushed 44 million people into poverty (Ivanic and Martin 2008). Worst hit were countries that imported most of their food and the poor whose diets relied heavily on staple grains.

This is the case for many countries in the Middle East and North Africa (MENA) region. Diets there depend heavily on wheat, which is largely imported (Table 1).[1] For example, between 2005 and 2007, Libya imported 98 percent of its wheat, and wheat generated 40 percent of the calories in the average Libyan diet. In Algeria, the comparable numbers were 69 and 46 percent. Consequently, spikes in international wheat prices create hardship for the region's poor and strain the resources of the public and private institutions that comprise the region's social safety net. To make matters worse, associated bouts of market volatility have made it difficult for households and governments to plan ahead.

Table 1: Selected wheat statistics, average 2005-07

	Net trade (Imports-Exports) (thousand ton)	Domestic consumption (thousand ton)	Trade share of domestic consumption (%)	Share of total calories from wheat (%)
Algeria	5,405	7,883	69	46
Bahrain	27	27	100	—
Egypt	7,569	15,267	50	35
Iran	510	15,200	3	43
Iraq	3,772	6,209	61	—
Jordan	848	830	102	38
Kuwait	294	294	100	23
Lebanon	313	450	69	30
Libya	1,430	1,455	98	40
Morocco	2,673	7,075	38	41
Oman	147	147	100	—
Saudi Arabia	85	2,500	3	27
Syria	-556	4,306	-13	39
Tunisia	1,596	2,933	54	48
United Arab Emirates	514	514	100	29
Yemen	2,166	2,311	94	38
MENA	26,793	67,404	40	—
Rest of the World	-26,793	548,788	-5	—

Notes: Estimates of the share of daily calories derived from wheat are taken from FAO (2011). The remaining data is from USDA (2011).

The recent periods of high and volatile food prices have prompted proposals for policies that use commodity storage as an instrument. For example, former French President Nicolas Sarkozy, when laying out an agenda for the French presidency of the G20, suggested that subsidized storage might be one way of mitigating volatile food prices (Hall 2010). During his tenure as Director General of the International Food Policy Research Institute, Joachim von Braun promoted the use of real and virtual food inventories to dampen food price volatility (von Braun and Torero 2009). And in a Financial Times Op-Ed piece, former World Bank President Robert Zoellick urged the establishment of small strategic reserves of food in disaster-prone areas (Zoellick 2011). The build-up of strategic reserves is also a key topic in the Middle East and North Africa (Lampietti et al. 2001; Wright and Cafiero 2011).

Just as wheat is an important commodity for the region, MENA is an important region for the global wheat market. Between 2008 and 2010, more than 29 percent of all exported wheat was destined for the region. Over the last decades, countries in MENA have added to their capacity to store grains, and wheat stocks have grown along with populations and demand. Precautionary policies led to an increase in the stock-to-use ratio as well, concentrating a greater share of global stocks in the region. From negligible levels in 1970, the region held more than 13 percent of global wheat stocks between 2008 and 2010, an amount equivalent to 15 percent of global wheat trade and 52 percent of MENA imports (USDA 2011). Consequently, decisions taken by the region about strategic stores of wheat are of increasing importance for global markets. Moreover, with production constrained by available land and water resources, and with significant population growth projected in MENA, the region's presence in global wheat markets is expected to grow.

In this paper, we examine whether stockpiles of wheat in the region could be used strategically to ameliorate the effects of sharp run-ups in international wheat prices. While public storage policies have been extensively studied in a closed economy, they have received less attention in the context of an open economy. Using a numerical model of competitive storage under rational expectations, we examine a strategic storage rule designed to insulate the region from the most severe price spikes, those that fall in the top 10 percent of the range of simulated prices. We find that the strategy can reduce the variability of domestic wheat prices and blunt the domestic impact of increases in global prices. In contrast to most policy approaches that countries use to insulate themselves from off-shore price disturbances, the strategy has positive spillover effects, reducing global price variability rather than increasing it. However, the strategy will sometimes fail, when consecutive negative supply shocks occur and MENA inventories are dissipated. The frequency of failure declines as larger inventories are held, but costs increase as well. By comparison, a pro-cyclical relief program that targets up to 40 percent of the population is a less expensive alternative.

Background

Poverty is at the core of the region's concerns about food security. About one-quarter of the population in MENA countries is poor and about three-quarters of poor people live in rural areas. Poor households in the region spend between one-third and two-thirds of their income on food, so they are hardest hit by food-price shocks. In addition, since a relatively high concentration of the population lives on incomes near the poverty line, small increases in the cost of living can have a large impact on the incidence of poverty (World Bank 2009).

The combination of diets heavily reliant on wheat and wheat supplies dependent on imports means that events in global wheat markets play an outsized role for welfare outcomes in the region, and this link between international markets and domestic welfare will likely strengthen with time. Population growth in MENA is projected to be 1.7 percent per year, significantly higher than the world rate of 1.1 percent (World Bank 2009). At the same time, the potential for expanding supplies on irrigated lands is severely constrained; per capita water availability is projected to fall by half by 2050, with serious consequences for the region's already stressed aquifers and natural hydrological systems (World Bank 2007). As a consequence, projections of the region's food balance indicate that imports will increase by almost 64 percent over the next twenty years (World Bank 2009).

When price shocks occur, governments often intervene. In MENA, the interventions come in many forms, but consumer subsidies are the most favored instrument (Lampietti et al. 2011). For example, in Tunisia, Jordan, Morocco, Egypt, Syria, and Iraq, where disaggregated data are available, food subsidies averaged 1.6 percent of GDP in 2009 and totaled $8.1 billion (World Bank 2011b). Since then many governments have expanded consumer subsidies in response to high commodity prices and popular uprisings.

At the same time, the capacity of governments to shore up safety net programs against high food prices differs among countries in the region (World Bank 2009, 2011b). All else equal, countries with large fiscal deficits and high cereal import dependency are least able to absorb a wheat price shock. These are mostly the oil importers (Jordan and Lebanon) and the region's developing oil exporters (Yemen, Iraq and Syria). In contrast, the Gulf Cooperation Council (GCC) countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates) have ample budgetary resources to absorb higher costs, even though they are entirely dependent on the international markets for their wheat. Moreover, in these countries rising food import bills are frequently offset by rising export revenue, because of the positive correlation between energy and food prices. Egypt and Morocco do not have the luxury of ample fiscal space to absorb sustained higher prices, although their higher domestic production levels help cushion price shocks.

Despite the preponderance of consumer subsidies, evidence suggests that international food price shocks are nonetheless transmitted to various degrees to domestic food prices throughout the region (World Bank 2011b). Over a five year period ending in February 2011, domestic food prices rose, on average, by more than 10 percent annually in Egypt, Iran, and Yemen, and by nearly 5 percent or more in Djibouti, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia and the United Arab Emirates. Rising international prices have been a major factor behind increases in domestic food prices, typically explaining some 20 to 30 percent of the variation in domestic prices (World Bank 2011b). International price changes have been particularly strong drivers of food inflation in Iraq and West Bank and Gaza, accounting for over 50 percent of the food inflation, followed by Egypt, Djibouti and the United Arab Emirates (over 40 percent of the food inflation). The pass-through is smaller but is still sizable, varying between 0.2 and 0.4 percent, for a large group of MENA countries, including Morocco, Jordan, Syria, Iran, Yemen, and all GCC countries other than United Arab Emirates.

Shared policy elements and effects

Over the past 50 years, most countries have come to depend on private markets for the physical distribution of food (Akiyama et al. 2001). However, this is less true for countries in the MENA region where food policies rely heavily on state interventions. With the exception of Yemen, wheat imports, marketing and storage are managed by public or semi-public entities. Moreover, with the exception of Libya where policies are in flux, all MENA governments provide consumer subsidies for wheat flour or bread.

Along with managed supplies, strategic inventories are a crucial element of food security strategies in the region. As mentioned, one consequence is that a large share of global wheat inventories is held in the region. In 2011, storage capacity in the region was sufficient to cover six months of average consumption, and estimated ending stocks stood at five months of average consumption (World Bank and FAO 2012). Although it is difficult to distinguish strategic storage from working stocks, it is worth noting that global wheat ending stocks stood at 3.6 months of global consumption for the 2010/11 crop year and 3.4 months for 2011/12 (USDA 2012). Moreover under current plans, inventory levels in the region will grow. For example, wheat agencies in Oman, Bahrain and Qatar plan to more than double their storage capacity. When the plans are fully implemented, agencies in those countries plus Syria and Saudi Arabia will have the capacity to store enough wheat to meet consumption needs for 13 to 17 months (World Bank and FAO 2012, p. 14). Planned expansion in Jordan, Algeria, Tunisia and Morocco will bring capacity in those countries to more than six months of consumption.

Although there are differences in how wheat supply chains are managed in MENA, supply chain costs are generally high relative to the costs in benchmark countries. This is true even though the dry climates of MENA help to limit spoilage and hold down physical storage costs. In fact, the average monthly cost of storing wheat in the region ranges between $1.5 and $3.5 per metric ton, which compares favorably with storage costs in the Netherlands and the United States, both large handlers of traded grain (World Bank and FAO 2012). Still, because stocks are held for long periods, total storage costs are high. Other components of the import supply are costly as well when compared to benchmark countries. Recent analysis suggests that the total costs of port logistics; storage; inland transport (to the mills); and management are on average $42 per metric ton of wheat or 12.5 percent of the cost of a ton of wheat at current prices. Moreover, there are significant differences among the countries, with supply chain costs in some countries four times those of the Netherlands (World Bank and FAO 2012, p. 28).

In this paper, our focus will be on the first two elements of food policy in MENA, the use of subsidies and strategic storage to deal with high and volatile wheat prices. But before proceeding, it is worth noting that policy changes and public investments could also be brought to bear on addressing high supply chain costs. In particular, money spent on strategic stores that lessen the negative consequences of price spikes could also be spent on improvements to roads or ports that reduce average prices.

Commodity stabilization policy experience

Early interest in the use of storage to stabilize commodity prices centered on macroeconomic considerations. In a gold-standard world, volatile export earnings and import costs arising from volatile commodity prices created challenges for managing exchange rates. Moreover, low commodity prices were seen as an exacerbating factor in the Great Depression. Consequently, commodity stabilization schemes and commodity-based currency rules were promoted by economists as diverse as Keynes (1938) and Hayek (1943). Later, Massell (1969) introduced the notion that commodity price stabilization could generate welfare benefits for the sector as a whole, which could be shared among producers and consumers.

Between 1954 and 1980, treaties among major producing and consuming countries resulted in five international commodity agreements with price stabilization component, three of which (tin, cocoa, and rubber) relied on managed buffer stocks to smooth international prices. National governments launched domestic stabilization programs as well. The European Union, Japan, and the United States all employed government-controlled inventories to help manage commodity prices; buffer stock schemes were launched in Bangladesh, India, Indonesia, the Republic of Korea, Mexico and the Philippines. In 1969, the IMF established a Buffer Stock Financing Facility to provide lending support to the stabilization efforts. The Common Fund for Commodities was established to provide liquidity to international stabilization programs under a UN initiated Integrated Program for Commodities established to stabilize the prices of ten core commodities in 1975 (Larson et al. 2004; Knudsen and Nash 1990).

During this period, a series of conceptual and empirical studies emerged to suggest that average welfare gains from stabilization were small, relative to changes in price levels (Newbery and Stiglitz 1981; Anderson et al. 1981; Myers and Oehmke 1988). Williams and Wright (1991) explored the interactions of public and private stocks in a series of pioneering papers, summarized in a 1991 volume. Their work and related studies showed that, because of resource limits, stabilization schemes are prone to eventual bankruptcy, even when they are rationally priced and hedged in financial markets (Wright 1979; Wright and Williams 1982, 1988; Larson and Coleman 1993). Other writers pointed out that choosing the appropriate price to defend is a technical challenge made more difficult in practice by political economy incentives to convert stabilization programs into programs that benefit dominant interest groups (Bauer and Paish 1952; Bardsley 1994).

Perhaps most convincing for policy makers were the insurmountable practical difficulties of implementing the stabilization mandate once policies were in place. Even well-run stabilization schemes strained budgets and many failed, sometimes in spectacular fashion, creating disruptions in the markets they were designed to stabilize (Yamey 1992; Bardsley 1994). By the 1990s the stabilization components of the international commodity agreements were no longer in force. Gilbert (1996) penned an obituary notice.

As evidence mounted showing that the theoretic benefits of stabilization were low on average and that the policies themselves were difficult to manage, a separate literature emerged showing that consequences of commodity risks were nonetheless significant for particular groups, especially vulnerable households and poor children. This large literature centered on how risk mitigation and adaptation were central to rural livelihood strategies, influencing agricultural production choices and spawning a variety of formal and informal insurance mechanisms. Larson et al. (2004) and Dercon (2005) provide reviews. In terms of policy, this line of literature often promoted instruments designed to mitigate the harsh consequences of commodity price volatility, rather than instrument meant to change the distribution of prices.

When stable crop prices spiked in 2008, price stability and poverty were linked again in the minds of policy makers, as prices pushed the near-poor into poverty. In response, governments intervened in markets and interest in price stabilization policies reemerged (Brinkman et al. 2010; Wodon and Zaman 2010). Moreover, the speed with which food exporters raised export taxes or banned exports in response to raising prices encouraged food importers to reconsider policies that would keep strategic stores of food within national borders (Abbott 2012; Liefert et al. 2012; Martin and Anderson 2012).

Still, while precautionary public stores are often a key component of food security programs, there are surprisingly few empirical studies that examine the cost tradeoffs between strategic storage and alternative policies.[2] This leaves a knowledge gap for policy makers, since other forms of investment can be viewed as complete or partial substitutes to investments in public storage. In this application, we focus on a comparison of the cost of holding strategic food stores versus targeted assistance, a frequently used alternative; however the model could also be used to analyze the effects of irrigation investments or varietal improvements that reduce domestic supply variations, or investments in trade corridors that lower transaction costs and average consumer prices.

The model

In this section we describe the model used to assess the effects of strategic storage policy on domestic prices in the MENA region and the rest of the world (RoW).[3] The intuition behind the model is that the equilibrium price of physical storage sits at the cusp of spatial and temporal arbitrage possibilities. Said differently, decisions about selling for consumption or trade today must be balanced against the expected profitability of storing. Expectations about the future value of stored goods are conditional, and, all things equal, price outcomes are expected to be higher and more volatile when carryover inventories are low. [4] This is because, when stocks are low, outcomes in which production short-falls are rationed through high-prices rather than buffered through stock draw-downs are more probable.

A key feature of the class of models, including the one presented here, is the need to form a rational set of numerical conditional price expectations, in order to value carry-over inventories and future production. Specifically, the model uses a set of spatial and temporal price arbitrage conditions, together with assumptions about demand, supply, and the distribution of supply shocks to model the distributions of price and consumption outcomes. With these as a baseline, policies are introduced that are meant to change price outcomes, and the consequences of the policy interventions on the distribution of prices and consumption are evaluated. It is worth emphasizing that the model is not a forecasting tool, but rather a way to evaluate strategic storage rules on price and consumption levels and volatility.

In order to make the numeric model tractable, we treat the region as a common market operating under a unified policy. This is a necessary abstraction, but not an altogether unreasonable one. As discussed, countries in the region pursue similar polices, and shared borders among the MENA countries, which are otherwise isolated from other regions by water or desert, means that potentially different market outcomes generated by differences among the policies are most likely muted through elicit trade. More to the point, an important collective outcome of the separate national policies has been a significant increase in the share of global wheat inventories held in the region, which are in turn managed primarily by parastatal agencies. Because this share is large, the set of similar policies has an aggregate effect on global markets. By collapsing the many similar policies and markets into representative ones for modeling purposes, we are able to capture this important aspect in our analysis. Indeed, the capacity to quantify the collective spillover effect of the region's similar policies is a key innovation of the model. We abstract as well from the technical and political-economy obstacles to implement the policy we simulate.

It is also worth pointing out that trade corridors remain available during our simulations, even though the capacity to restock strategic stores is constrained. This sidesteps a sometimes stated concern by policy makers that trade corridors will be shut down. Still, while it is possible to imagine scenarios where governments have the capacity to distribute strategic stores of wheat but import supply chains are cut, real world instances have been few in recent times and brief in duration.[5] More common are political events or acts of nature that disrupt deliveries from contracted suppliers and drive import prices higher. Our modeling approach is consistent with the latter set of events, but not with the first. Potentially, the model could be modified to include discontinuities in trade if reasonable probabilities of such events could be formulated. Since we have not done so, any benefits ascribed to strategic stores as a precaution against discontinuous trade are omitted.

Model equations

Formally, the model is characterized by the following relationships. Current consumption in region i, where $i \in \{\text{MENA}, \text{RoW}\}$, is given by a downward sloping function of current price:

$$D^i(P_t^i) = a^i - b^i P_t^i, \tag{1}$$

where P_t^i is the price of wheat in period t and region i.

In each region, there is a representative storing agent that acts competitively and incurs the following cost for storing an amount S_t^i from period t until $t+1$:

$$K(S_t^i) = (1+r)(kS_t^i + P_t^i S_t^i), \tag{2}$$

where $k \geq 0$ is the net unit cost of physical storage services, r is the interest rate; both are assumed to be identical in the two regions. Accounting for the non-negativity constraint on storage, the first-order condition of the storer's problem yields the following complementarity condition[6]

$$S_t^i \geq 0 \ \perp \ P_t^i + k - E_t P_{t+1}^i/(1+r) \geq 0, \tag{3}$$

where E_t denotes the mathematical expectations operator conditional on information available at time t. This implies that storage occurs when there is an expectation that the returns to storage, net of the time value of money and physical storage costs, are positive. It should also be emphasized that the evaluation is based on an expected price for period $t+1$. The formulation of this expectation is a key aspect of the numeric model.

Production is uncertain in the model. Representative producers make their production choices and pay for inputs one period before bringing output to market. We represent that choice, made in period *t,* as planned production, $\overline{H}_t^i$. Actual and realized production differ by a multiplicative exogenous disturbance term, ε_{t+1}^i , centered on one, so that stochastic revenue is defined as $P_{t+1}^i \overline{H}_t^i \varepsilon_{t+1}^i$. The producer's choice is based on information and input prices in period t and can be written as:

$$\max_{\overline{H}_t^i} E_t(P_{t+1}^i \overline{H}_t^i \varepsilon_{t+1}^i)/(1+r) - \Psi^i\ (\overline{H}_t^i), \tag{4}$$

where ε_t^i is normally distributed with a mean of 1 and a variance of σ_i^2; $\Psi^i(\overline{H}_t^i)$ is the production cost corresponding to the planned production. The solution of this problem is the following equation

$$E_t(P_{t+1}^i \varepsilon_{t+1}^i)/(1+r) = \Psi^{i'}(\overline{H}_t^i). \tag{5}$$

Note from equation (5) that, contrary to storing agents, producers do not base their production plans on price alone, but consider marginal expected revenue, which includes an expectation about prices and the likelihood of price-correlated production surpluses or shortfalls.

Differences between production, consumption and storage in either location are balanced by trade. We assume that wheat is a homogeneous product, so that trade is decided by the spatial arbitrage condition:

$$X_t^i \geq 0 \ \perp \ P_t^i + \theta \geq P_t^j \ \mathit{for}\, j \neq i, \tag{6}$$

where X_t^i is the export from region i, and θ is the per-unit transaction cost, inclusive of transport costs. For the problem at hand, we assume that transaction costs are constant over the relevant time horizon and do not depend on the direction of trade,[7] so that prices in MENA fall within a moving band that is defined by the RoW price and trade costs:

$$P_t^j - \theta \leq P_t^i \leq P_t^j + \theta \ \mathit{for}\, j \neq i. \tag{7}$$

At any point in time, three predetermined variables per country determine the state of the model: carry-in stocks, S_{t-1}^{i}; planned production, $\overline{H}_{t-1}^{i}$; and the period shock, ε_{t}^{i}. The latter two variables determine actual production and the three can be combined in one state variable, private availability, A_{t}^{i}, the sum of production and private carry-over:

$$A_t^i \equiv S_{t-1}^i + \overline{H}_{t-1}^i \varepsilon_t^i. \tag{8}$$

so that market equilibrium can be written as

$$A_t^i + X_t^j = D^i(P_t^i) + S_t^i + X_t^i \; for \, j \neq i. \tag{9}$$

To summarize, the numeric problem has two state variables, $\{A_t^{\text{MENA}}, A_t^{\text{RoW}}\}$, and eight response variables, $\{P_t^i, S_t^i, H_t^i, X_t^i\}$ for $i \in \{\text{MENA, RoW}\}$. Solutions follow a dynamic path since stocks are carried from one period to the next.

Calibrating the model and finding a numerical solution

The parameters for the model are chosen such that, at the non-stochastic steady state, the equilibrium reproduces the physical trend of the world wheat market in 2011 (Table 2). From the center panel of the table, we can see that the MENA region is a significant net importer, with imports of around 47 percent of its consumption. To calibrate the steady-state prices, we decided not to rely on 2011 values, which as discussed are high by historical standards, since it is unlikely that the steady state is associated with extreme values. Instead, we calibrate the rest of the world price at $176/ton, the average US export price in 2005-2007, a period prior to the high prices of the food crisis but during a time when prices had risen above prevailing prices at start of the decade.[8] The steady-state MENA price is defined by assuming that the price difference between the regions reflects transport costs, which is set at $35.55/ton based on a recent survey (World Bank 2012).

Picking appropriate elasticities is a challenge given the large variation in elasticities reported in the literature. As a guide, we follow the literature on commodity price dynamics, which shows that observed price volatility is consistent with relatively low demand elasticities (Roberts and Schlenker 2009; Cafiero et al. 2011), and assume the demand elasticity to be equal to –0.12, which is toward the lower end of commonly used elasticities. We consider a supply elasticity of 0.2, in line with commonly used supply elasticities for wheat.[9] The cost function is assumed to be quadratic, making the marginal cost function linear. We express the marginal cost function as

$$\Psi^{i\prime}(\overline{H}_t^i) = c^i + d^i \overline{H}_t^i. \tag{10}$$

The parameters c^i and d^i determine the supply elasticity (see Table 2), under the assumption that marginal cost at steady-state production equals the steady-state price.

We specify two sets of uncorrelated supply shocks, $\varepsilon^i \sim N(1, \sigma_i^2)$. Based on historical production data, we derive an estimated distribution of supply shocks, where production in MENA is more volatile than in the rest of the world. Annual interest rates and per unit storage charges are assumed to be the same for each region at 5 percent and $22.40 per ton, based on a recent World Bank study on wheat markets in MENA (World Bank 2012).

Table 2: Model calibration values

Parameter	**Economic interpretation**		**MENA**	**RoW**
a^i	Intercept of demand curve		84.336	664.048
b^i	Slope of demand curve		0.043	0.404
c^i	Intercept of marginal cost function		-805.905	-670.476
d^i	Slope of marginal cost function		25.059	1.335
std(ε^i)	Standard deviation of production shocks		0.07	0.03
r	Interest rate (%)		5	
k	Physical storage cost ($/ton)		22.4	
θ	Trade cost ($/ton)		35.55	
Calibration target at steady state			**MENA**	**RoW**
Consumption (million ton)			75.3	592.9
Production (million ton)			40.2	628
Price ($/ton)			211.55	176
Demand elasticity			-0.12	
Supply elasticity			0.2	
	Simulated		**Observed**	
Coefficient of variation (%)	**MENA**	**RoW**	**MENA**	**RoW**
Price	16.36	19.63	—	17.85
Exports	—	8.58	—	10.61
Demand	1.98	2.38	1.16	1.68
Production	7.01	3.04	7.54	3.46

Notes: Consumption, production and price in RoW targets are determined as the trend values in 2011 after applying an Holdrick-Prescott filter (smoothing parameter of 400) on the underlying data (USDA 2011, for consumption and production and World Bank 2011a, for the price). RoW consumption is adjusted to ensure global market equilibrium. MENA price target is defined by adding transport cost to RoW price. Simulated statistics are calculated over 100,000 sample observations from the asymptotic distribution.

The rational expectations storage model lacks a closed-form solution so solutions must be approximated numerically. The algorithm we use is based on a projection method inspired by Miranda and Glauber (1995) and described in detail in Gouel (2013).

Calibrated model behavior

Recall that the model is calibrated around a set of prices and quantities, together with two distributions of supply shocks that the model randomly draws on in simulation. Because of this structure, the mean values of the simulated series will be near their calibrated values. However, the variations in the simulated variables are affected by the sets of randomly drawn supply shocks. Because these distributions are not specified directly, we use the ex post variability in the simulated distributions of price, demand, supply and trade as to provide a validation check on the aggregate consequences of our ex ante parameter selections. With this as background, the simulated and historical coefficients of variation are reported in the bottom panel of Table 2. As the table makes clear, orders of magnitude are similar between the historical and simulated distributions.

Before moving to a discussion of alternative policies, a couple of points should be made about trade and storage outcomes in the baseline model. First, given the large gap between production and demand in MENA, the simulated model never generates an outcome in which wheat is exported from the region. This is consistent with expectations since MENA has not been a net exporter of wheat in the last fifty years.

The second point has to do with speculative storage—that is, storage that is held in order to profit from expected temporal price changes. Reported data series, including the data used to calibrate the model, contain all forms of storage: speculative storage, public storage, and pipeline storage that is needed to keep shipping and processing operations running smoothly. It is impossible to isolate speculative storage in the data; however, it is speculative storage that is key to the model's pricing mechanics. Conceptually, when one country is a perpetual importer, speculative storage will always take place in the exporting country, absent physical impediments to trade, large differences in physical storage costs or changing transfer costs (Gouel and Jean 2012). This is because an importing speculator pays interest on the costs of importing in addition to interest on the price of the commodity, a cost that a speculator in an exporting country does not incur. Unless there is an offsetting benefit to storing locally, competition will result in adjustments in trade rather than storage in response to changes in availability in the importing country.[10] This general finding applies to our model outcomes as well, and speculative private storage always takes place outside of MENA.

Strategic storage

In this section, we describe a regional cooperative strategy, where strategic inventories of wheat are held in MENA as a hedge against high global prices. In keeping with our earlier discussion, the objective of the cooperative strategy is to mitigate the consequences of price spikes, that is, brief periods of exceptionally high prices like those experienced in 2008 and 2010. Government interventions are designed to be rare in order to manage the costs of the program, which include the costs associated with displacement of private storage by government storage.

As discussed, there is no speculative storage in the MENA region in the benchmark model. However, we assume that MENA governments hold strategic reserves, which are not directly available for consumption unless released by managers of the strategic reserves, who follow strict rules. Furthermore, we assume that the goal of the strategy is to stabilize domestic prices rather than to directly influence global prices; a practical implication is that exports are prohibited when stocks are released.

Three inter-related components are needed to fully define the public intervention. The first has to do with the maximum domestic price the strategy hopes to defend. As discussed, most programs designed to stabilize domestic or international prices through the build-up and release of strategic stock-stabilization are prone to failure because they set out to defend unrealistic price goals. What's more, even when goals are set reasonably, inventories are depleted when rare but eventual combinations of events occur, for example, consecutive bad harvests. With this in mind, we have chosen a conservative strategic reserve objective for our simulation. Based on the benchmark model, we simulated the range of MENA price outcomes and from the resulting distribution of prices, picked the starting point for the highest decile—that is, the minimum price that is above 90 percent of the simulated price outcomes; this works out to be $263 per ton. Importantly, by choosing to intervene at the 90th percentile, the policy insures that interventions will be rare. It is also the case that, because the policy targets a thinning portion of the probability density function, most price outcomes above-the-trigger are expected to cluster near the target price. To summarize, choosing the 90th percentile means that most strategic interventions will occur when prices are slightly above the target price, and conversely, large gaps between world prices and the target price will be rare.[11]

A second decision sets the desired size of the strategic reserve, the target storage goal. This decision affects the robustness of the strategic policy because, when high prices do occur, domestic prices can only be lowered if there are sufficient supplies of wheat to be released from storage. When stocks are exhausted, domestic prices can rise above the target level. Said differently, the program fails less frequently as the size of the government's strategic reserve increases.

The third decision relates to how aggressively MENA wants to build toward its target storage goal. When the domestic price is below the price threshold and strategic inventories are below the target storage goal, MENA will add inventories at a given rate. Logistical capacity constraints will likely limit the rate of build-up, and there may be additional factors as well, for example a desire to spread the cost over multiple fiscal years. A larger build-up rate reflects a more aggressive storage strategy and results in a faster recovery when stocks are drawn down. A lower rate spreads out the buying and buildup of stocks over a longer time period and diversifies price risk.

The decision rules can be written out more formally as follows. The rules to build stocks or release them can be summarized by the following complementarity equation:

$$0 \leq \mathrm{S}_{\mathrm{t}}^{\mathrm{G}} \leq \bar{\mathrm{S}}^{\mathrm{G}}\left(\mathrm{S}_{\mathrm{t-1}}^{\mathrm{G}}\right) \perp \mathrm{P}_{\mathrm{t}}^{MENA} - \mathrm{P}^{\mathrm{C}}, \tag{11}$$

where S^G is the public storage level in MENA; P^C is the price ceiling; and $\bar{S}^G\left(S_{t-1}^G\right)$ is a capacity constraint in period t that public storage cannot exceed. This public storage behavior is accounted for by other agents and affects their expectations. Accordingly, we have to modify some equations from the previous model to accommodate public storage. In contrast to equation (9) in the benchmark model, market equilibrium in this situation takes the following form:

$$\mathrm{S}_{\mathrm{t-1}}^{\mathrm{G}} + \mathrm{A}_{\mathrm{t}}^{MENA} + \mathrm{X}_{\mathrm{t}}^{RoW} = \mathrm{D}^{MENA}\left(\mathrm{P}_{\mathrm{t}}^{MENA}\right) + \mathrm{S}_{\mathrm{t}}^{MENA} + \mathrm{S}_{\mathrm{t}}^{\mathrm{G}}. \tag{12}$$

As discussed, wheat exports never emanate from MENA in the benchmark model even though they are not explicitly constrained. This helps us simplify our equilibrium specifications in the strategic reserve model. To prevent released strategic reserves from being exported, we suppress MENA export equation (equation (6) for $i = \mathrm{MENA}$ in the benchmark model), and MENA exports from rest of the world market equilibrium.

At every period, restocking cannot exceed the quantity $\alpha\bar{\bar{S}}^G$, where $0 \leq \alpha \leq 1$ is the build-up rate, and $\bar{\bar{S}}^G$ is the targeted size of the strategic reserve. Since public stocks cannot exceed $\bar{\bar{S}}^G$, the restocking rule can be expressed as

$$\bar{S}^G(S^G_{t-1}) = \min(\bar{\bar{S}}^G, \alpha\bar{\bar{S}}^G + S^G_{t-1}). \quad (13)$$

The previous-period public storage level enters the model as a state variable, since it affects the current-period equilibrium. Consequently, the public intervention problem has three state variables, $\{A_t^{\text{MENA}}, A_t^{\text{RoW}}, S_{t-1}^G\}$, and eight response variables, $\{P_t^i, S_t^i, H_t^i, X_t^{\text{RoW}}, S_t^G\}$ for $i \in \{\text{MENA}, \text{RoW}\}$.[12]

Simulation outcomes

Parameter interactions

As discussed, the intervention price is set high and is designed to protect against the highest ten-percent tail of the expected price distribution. Choices about the targeted size of the reserve and the rate at which it is replenished determine the robustness of the policy. For the analysis reported in this section, the model is simulated 100,000 times for each of three buying strategies (10, 50 and 100 percent replenishment rates) and a range of target inventory levels from no strategic reserves (the benchmark model) to a target reserve equivalent to 70 percent of steady-state consumption, which is equivalent 1.5 years of steady-state imports. For a given starting point, outcomes depend on the realized supply shocks, and it is only by simulating over several possible sequences of shocks that probable outcomes merge to an expected trajectory.

Still, it is worth emphasizing that it is the infrequent and extreme price events that most concern policy makers. In particular, the model simulations reveal that when global prices are high enough to trigger a release of inventories, the gap between domestic prices and the target prices is frequently small and a partial release of stocks is sufficient to drive down both domestic and international prices.[13] However, a large shock can deplete reserve stocks completely, allowing prices to exceed the target price. If an unfortunately timed second negative shock occurs before stocks can be rebuilt, the safeguard policy fails again. This illustrates two seemingly contradictory results that are nonetheless intrinsic characteristics of strategic reserves: strategic reserve policies are capable of successfully defending a target price for many years but fail eventually, even when reserve levels are large and the target price is set high.

Stabilization results

The tradeoffs among the strategic storage rules are illustrated in Figure 1. A range of targeted reserve levels are reported along the horizontal axes of the figure's panels while variables of interest are reported on the vertical axes.

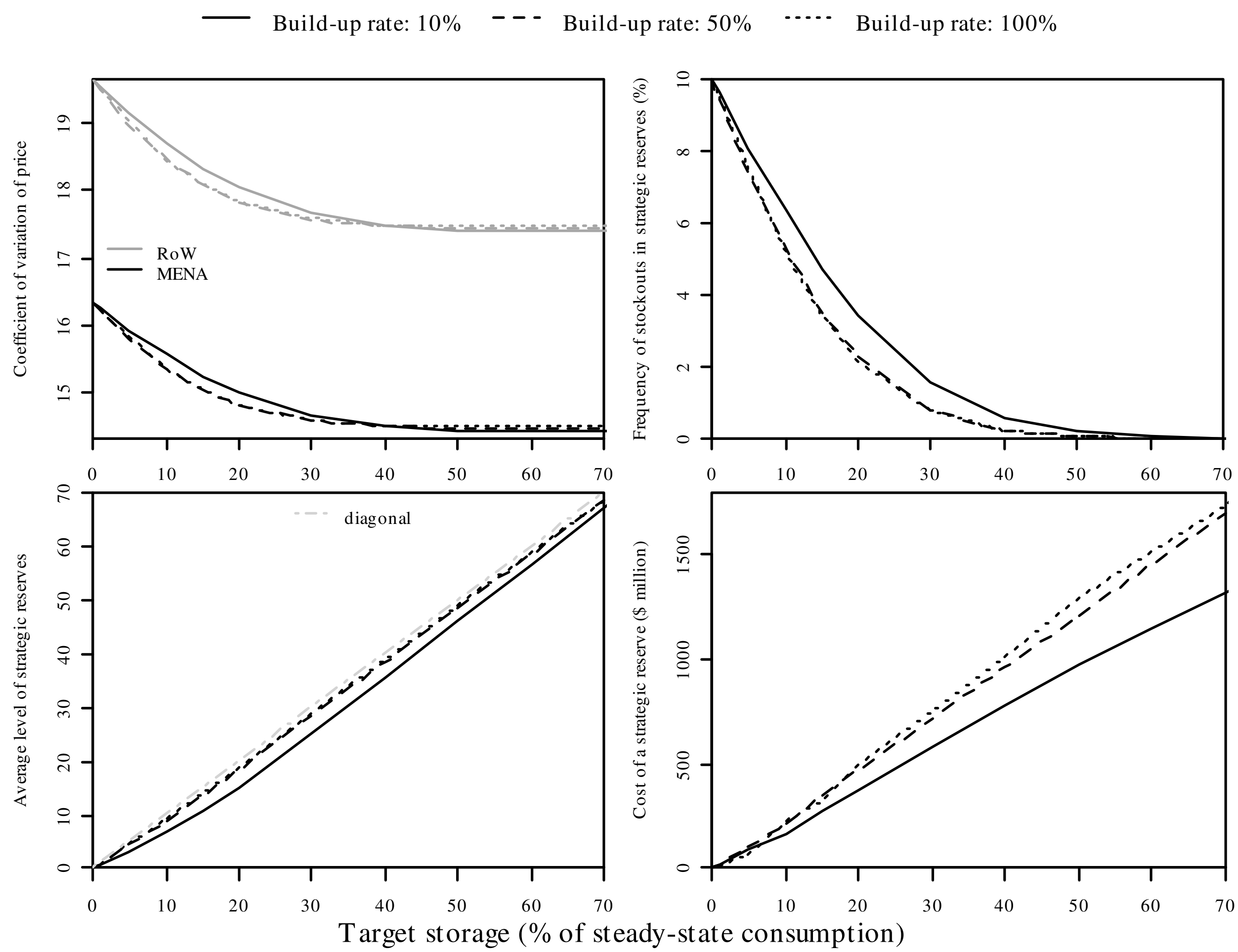

Figure 1: Effects of a strategic reserve policy for various levels of target storage.

Note: Statistics calculated over 100,000 sample observations from the asymptotic distribution. Data reported in the Figure is available as supplemental material on-line at the World Bank Economic Review.

Turning first to the upper left-hand-side panel, simulation results suggest that the strategic reserve can be effective in lowering the overall variation in domestic prices, and that the efficacy of the policy increases as the level of strategic stores is set higher. For example, at a restocking rate of 10 percent, a targeted reserve rate of 20 percent of consumption and a target price at the 90th quantile, the strategy reduces the coefficient of variation (CV) for MENA wheat prices from 16.4 to 15, and reduces the CV of domestic consumption from 1.98 to 1.81. Increasing the restocking rate from 10 percent to 50 percent increases the robustness of the policy as the probability of a stockout falls from 3.4 to 2.3 percent. This, in turn, boosts the performance of the strategic reserve policy, further reducing domestic price and consumption volatility to 14.8 and 1.79 percent.

An important outcome from the model is that the strategic reserve policy, designed to protect domestic consumers, lowers the volatility of prices in the rest-of-the world as well. Indeed, a comparison of the upper and lower portions of the first panel of Figure 1 shows that, because of trade, the coefficient of variation of price in RoW evolves similarly to the CV in MENA. By design, there are periods when the stocks released under the strategy are large enough to completely displace imports into MENA. However, this occurs infrequently, partly because the targeted price is set high and is rarely breached. In fact, the full displacement of MENA imports occurs less than 0.1 percent of the time and only occurs at target storage levels of at least 30 percent of normal consumption. In very rare instances, the correlation between local and RoW prices is also re-established when the trigger is breached, but stocks are insufficient to insulate domestic consumers.

As discussed, an aggressive strategy of restocking reserves lowers the chance that sequential periods of high prices will deplete the reserves. However, while supply shocks may be uncorrelated, high prices are not since low inventory levels can persist, setting the stage for sequential periods of high prices. An aggressive restocking rate means that the reserve manager is more likely to add more reserves when international availability is tight and prices are high. Consequently, the relationship between the coefficient of variation of price and the build-up rate is not monotonic. For low reserve targets, prices are less volatile with a higher build-up rate, but the opposite is true for high target reserves. As the size of the reserve builds, the probability of a stockout falls significantly even at low restocking rates. Consequently, a more aggressive restocking policy becomes destabilizing since larger interventions reduces the quantities available for consumption and private storage, but yield only small increases in the capacity of the policy to withstand sequential periods of high prices, and therefore generate small marginal reductions in price volatility.

Before proceeding to a discussion of program costs, two additional consequences of a MENA strategic storage policy on global markets should be mentioned. First, because wheat imports are sped up during periods of stock accumulation and are displaced when public inventories are released, the effect of the policy on trade is unambiguous and generates increased rates of trade volatility.[14] For example, the CV of trade increases from 8.6 to 12.2 percent for a 20 percent target reserve with a 10 percent build-up rate. Public storage also has an effect on private storage, through two channels. First, by decreasing price volatility, public storage decreases the profit opportunities from speculation and the incentive to store privately. Second, public reserves follow a predictable storage rule that can be exploited by speculators, either by running on the public stocks or by strategically dumping private reserves into the program. In the policy we examine, a run on public reserves (as in Salant 1983) is unlikely since the intervention price is quite high. Under the scenarios we simulate, the level of global stock increases because of the policy, but this is accomplished partly at the expense of speculative storage. Moreover, under a strategic reserve program private storage starts to accumulate stocks at much higher availability levels when the release of public stocks is less likely.

<u>Program costs</u>

The direct costs of the strategies are provided in the fourth panel of Figure 1, based on the following:

$$[1-1/(1+\mathrm{r})]E_0\sum_{\mathrm{t}=0}^{\infty}(1+\mathrm{r})^{-\mathrm{t}}\left[\left(\mathrm{P}_\mathrm{t}^{MENA}+\mathrm{k}\right)\mathrm{S}_\mathrm{t}^\mathrm{G}-\mathrm{P}_\mathrm{t}^{MENA}\mathrm{S}_{\mathrm{t}-1}^\mathrm{G}\right], \tag{14}$$

where the discount rate used to calculate costs is the same rate used to discount storage costs. It should be kept in mind that the calculation is strictly one of costs and not net benefits which ultimately depend on assumptions about risk aversion in MENA and the RoW.

The annual average cost of the strategic reserve program evolves almost linearly with the targeted size of the strategic reserve. For a 10 percent build-up rate and a target at 20 percent of normal consumption, the annual cost of the policy is $373 million. Program costs increase rapidly as the target storage goal increases, climbing to $1,319 million for a target equivalent to 70% of annual consumption. As discussed, the marginal market effects of increasing reserves fall quickly once the reserve target moves beyond 40 percent of consumption (87 percent of trade). A more aggressive restocking rule raises the average purchase price for the strategic reserves and this drives up program costs as well. Depending upon the restocking rate, the gains to increasing the target storage level flattens out and little is gained even while program costs rise in a linear fashion (Figure 1). For example, a strategy that sets a reserve target at 40 percent of annual consumption with a restocking rate of 10 percent, achieves nearly the same reduction in price volatility as do more expensive alternatives strategies with higher reserve targets. The strategy reduces domestic price volatility from 16.4 to 14.5 percent, reduces international price volatility from 19.6 to 17.5, and reduces demand volatility from 1.98 to 1.75. The program is expected to fail 0.58 percent of the time and cost $782 million per year to maintain. While the failure rate is low overall, keep in mind that, because the trigger price is set at the high end of the price distribution, no intervention is required 90 percent of the time. Consequently, a less sanguine interpretation of this result is that the policy will fail, completely or partially, about 5.8 percent of the time interventions are needed. Beyond this point, program costs continue to rise without significantly increasing the robustness of the program.

<u>Targeted transfers</u>

Often governments find it more cost effective to target the most vulnerable for assistance. The basic notion is that some portion of society can rely on its own resources even in times of high food prices, and excluding them from safety-net programs lowers program costs. With this in mind, we consider an alternative food security policy in which only a targeted group is protected during high-price periods. The alternative policy allows domestic prices to fluctuate as markets dictate, but provides direct assistance in the form of food coupons to a targeted group, permitting them to purchase wheat at the targeted price. Contrary to a storage policy, there are no physical inventories and the targeted program does not fail as long as the government is willing and able to fund it. Because public inventories are not stored in support of the program, costs are only occurred when prices breach the targeted price.

Before continuing, it should be pointed out that there are alternative ways of structuring targeted food safety nets.[15] There are also alternatives ways to manage the financing of safety net programs, drawing on financial risk-management instruments, including options, weather insurance or catastrophe bonds (Alderman and Haque 2006; Mahul and Ghesquiere 2007; Skees et al. 2005). However for our purposes, cash-equivalent transfers. where the program's cost falls to the government, serve as a realistic, useful and simple benchmark with which to compare program costs.

In the context of the model, the market equilibrium equation for MENA under the new policy is:

$$\mathrm{A}_{\mathrm{t}}^{MENA} + \mathrm{X}_{\mathrm{t}}^{RoW} = (1-\lambda)\mathrm{D}^{MENA}\left(\mathrm{P}_{\mathrm{t}}^{MENA}\right) + \lambda\mathrm{D}^{MENA}\left(min(\mathrm{P}_{\mathrm{t}}^{MENA}, \mathrm{P}^{\mathrm{C}})\right) + \mathrm{S}_{\mathrm{t}}^{MENA} + \mathrm{X}_{\mathrm{t}}^{MENA}, \qquad (15)$$

where λ represents the share of households covered by the policy. The costs associated with implementing the identification and targeting of qualifying households is excluded, even though the costs may be very consequential. The cost of this policy is given by:

$$[1 - 1/(1+\mathrm{r})]\lambda E_0 \sum_{\mathrm{t}=0}^{\infty} (1+\mathrm{r})^{-\mathrm{t}} \left[max\left(\mathrm{P}_{\mathrm{t}}^{MENA} - \mathrm{P}^{\mathrm{C}}, 0\right) \mathrm{D}^{MENA}\left(min(\mathrm{P}_{\mathrm{t}}^{MENA}, \mathrm{P}^{\mathrm{C}})\right)\right]. \qquad (16)$$

Simulation results show that because the trigger price sits at the 90th quantile, payouts occur infrequently. Moreover, because the program covers the thin tail of the price probability distribution, prices that would warrant payouts are clustered near the trigger and this keeps typical payouts low. In turn, these features keep average program costs down to $53 million per year, when 40 percent of the population is covered, well under the cost of a strategic storage program. The cost of the program expands linearly with the share of the population covered and, even when targeting is dropped and the program is extended to the entire population, average program costs are low at $142 million per year.

Nevertheless, the average cost of the program masks rare events that may strain budgets and threaten the sustainability of the program. In our simulation, the maximum payouts for a program-coverage of 40 percent of the population, was $3.78 billion—nearly 70 times average costs. At the same time, the value was an extreme one and 99 percent of the payouts were under $1.34 billion (about 25 times average cost).

The policy is designed to allow vulnerable households to consume at levels consistent with lower prices when wheat prices are high. For some households, the benefits are large and lasting, since the capacity to purchase more food precludes the long term consequences of even temporary periods of poverty and malnutrition. But it also means that, for the portion of the population covered, price does not ration demand. Specifically, when the market price reaches the ceiling price, protected consumers face a constant price and their demand becomes perfectly inelastic to market prices. As a consequence, the program creates an added cost for most consumers, since less adjustment in demand leads to greater price volatility, both in MENA and in the rest of the world. Quantitatively, simulations suggest that the average effect of the policy on volatility is small. The CV of global prices increases marginally from 16.36% to 16.60%, even when the program is extended to all households in MENA

Sensitivity analysis

In the sections above, we considered variations in target storage levels and the restocking (build-up) rate on price outcomes, and then compared the costs of the strategic storage policy to an alternative program that provides targeted relief to the most vulnerable when prices are high. Implicit in the analysis is the assumption that the parameters in the calibrated model are sound. In this section we report on results based on alternative assumptions about supply and demand elasticities, and interest rates. What the sensitivity analysis shows is that these basic model assumptions do influence the quantitative results, but do not affect any particular conclusion. To manage the number of alternative results that we report, we dispense with multiple restocking scenarios and focus exclusively on the case where inventories are immediately replenished. These results are summarized in Figure 2.

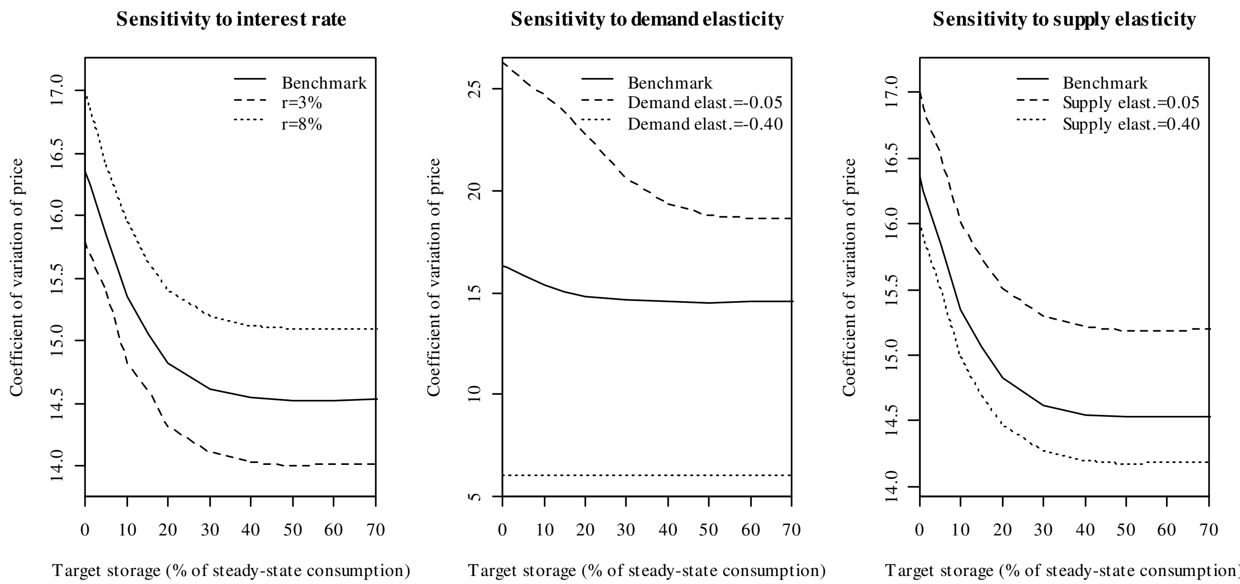

Figure 2: Sensitivity analysis to interest rate, demand elasticity, and supply elasticity (with 100% build-up rate)

Interest rate

We considered two interest rates: 3 and 8 percent, while the benchmark used in the paper was 5 percent (Figure 2, left panel). A lower (higher) interest rate makes storage for speculation more (less) profitable by decreasing (increasing) the opportunity cost of storage. The effect on price volatility is limited as a lower interest rate of 3 percent decreases the coefficient of variation of price by less than one point. The policy effects are not sensitive to the interest rate: the results are just translated with respect to the effect of interest rate on the volatility without policy. Said a bit differently, the benchmark results are affected by interest assumptions, but the effects of policy on benchmark volatility are limited.

Demand elasticity

We consider two alternative demand elasticities: a very inelastic demand curve with an elasticity of -0.05 and a more elastic one with an elasticity of -0.40. The benchmark value is -0.12. The results are shown in the second panel of Figure 2. With a more inelastic demand function, the benchmark price CV in MENA increases to 26 percent, significantly higher that global rates observed and simulated in our baseline model (recall Table 2).

Consequently, a higher target stock level is needed for the reductions in price volatility to level out, since price plays a smaller role in rationing demand. Conversely, the opposite is true with a more elastic demand function; prices are already very stable (with a price CV of 6 percent) and rarely spike. Consequently the policy has negligible impacts as public stocks are rarely sold. Still, it should be pointed out that the coefficients of variation under the alternative demand elasticities are inconsistent with the price distributions observed historically.

Supply elasticity

We consider supply elasticities of 0.05 and 0.40, with a benchmark equal to 0.20. The overall effects of changing supply elasticity are limited. As expected with lower (higher) supply elasticity, price volatility is higher (lower), but not overly so since price volatility without intervention does not change by more than 0.5 percent (third panel of Figure 2). As with interest rates, the primary effect of changes in the calibrating supply elasticity is on benchmark price volatility rather than how price volatility declines as public stock targets are increased.

Conclusions

In this paper, we describe a rational expectations model of competitive storage and trade, based on wheat markets for the Middle East and North Africa and the rest of the world. We use the model to quantify the effects of a strategic inventory policy designed to protect consumers in the region from very high prices. We find that, with a modest protection goal, the program can effectively shield consumers in MENA against steep price spikes, and by doing so lowers price volatility in the region. Moreover, because MENA is a large importer, releasing stocks when international prices are high lowers international prices since the released stocks displace MENA imports. Theory and practical experience suggest that strategic reserve programs fail when a series of rare but eventual adverse events occur. The model suggests the probability of the program's failure can be reduced by holding greater reserves. A more aggressive restocking of spent reserves reduces failure risk as well, but the strategy can be destabilizing since larger purchases are made when international supplies are tight. Sensitivity analysis shows that these findings are robust to changes in how the model is calibrated.

Making the strategic reserve program robust to failure drives up the program's costs. In practice, targeted assistance through cash or in-kind transfers, work programs and other channels are often used to address food vulnerability and there is a growing knowledge base on how best to implement them. Simulations show that a targeted consumer subsidy program that insulates the most vulnerable from the upper range of price increases is a much less expensive alternative on average. The simulations also demonstrate that financing targeted transfers in MENA requires planning since subsidy expenditures are also subject to eventual spikes that could undermine the policy when peak expenditures are not hedged. From a global market perspective, pro-cyclical transfer programs add slightly to price volatility. Transfer programs also rely on continuous trade, and while physical disruption to trade are infrequent and brief, governments that rely on transfers rather than strategic stocks should have contingent plans.

A complementary policy of investing in trade corridors is a promising area for future study. Policy changes and public investments that lower transaction costs in MENA to benchmark levels would confer immediate benefits in the form of lower average consumer prices and, to the extent they lead to robust or redundant supply channels, could address concerns about potentially debilitating supply disruptions.

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Notes

[1] For the purposes of this paper, the MENA region includes Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen.

[2] Exceptions include Srinivasan and Jha (2001), Brennan (2003), and Gouel and Jean (2012).

[3] The trade-and-storage model was developed in Williams and Wright (1991, Ch. 9), and analyzed in Miranda and Glauber (1995), and Makki, Tweeten and Miranda (1996). Early work on rational inventory pricing includes Gustafson (1958) and Gardner (1979).

[4] Stockouts (Wright and Williams1982), convenience yields (Makki, Tweeten and Miranda 1996), and risk premia (Larson 2007) are sufficient to generate this feature.

[5] For example, unrest during the Arab Spring led to supply disruptions at ports in Egypt, Libya, Syria and Yemen and contributed to food shortages (World Bank and FAO 2012).

[6] The "perp" notation ($\perp$) used in the complementarity condition means that the expressions on either side of the sign are orthogonal, so that if one equation holds as strict inequality, the remaining side holds as a strict equality.

[7] In practice, the MENA region does not export wheat, so the assumption of symmetric trade costs is innocuous.

[8] Average annual prices are for US hard red winter wheat, as reported by the World Bank (2011a).

[9] See, for example, FAPRI's elasticity database, available on the internet at http://www.fapri.iastate.edu/tools/elasticity.aspx).

[10] The result arises because we compress an annual cycle into a single period in the model. If trade takes time, it is rational to store while awaiting shipments (Coleman 2009).

[11] Note that "high prices" are defined by the model; that is, stochastic supply shocks are used in conjunction with the calibrated model to generate a consistent baseline distribution of domestic prices absent government intervention.

[12] We are unaware of another study analyzing this kind of policy, although it resembles the "price-peg" studied in the context of a single market by Salant (1983) and Williams and Wright (1991).

[13] When stocks in MENA are released, imports into MENA are displaced. When prices are only slightly above the trigger prices, small displacements are sufficient to bring international prices to a point where domestic prices are at the trigger price.

[14] For non-oil exporters in the region, food imports can affect exchange rates with macroeconomic consequences. For many years, the IMF issued loans to address trade shocks from high grain prices. See IMF (1996) for an instance involving Algeria.

[15] Cash transfers are increasingly used in developing countries, in part due to new technologies that lower implementations costs (Ahmed 2005). But targeted and self-targeted food transfers are still much used; Moreover, there are reasons for preferring food transfers to income transfers when food markets perform poorly (del Ninno, Dorosh, Subbarao 2007; Sabates-Wheeler and Devereux 2010; Cunha, De Giorgi, Jayachandran 2011). Magen et al. (2009) explore transfer programs in the context of food crises.