In times of highly volatile commodity markets, governments often try to protect their populations from rapidly rising food prices, which can be particularly harmful for the poor. A potential solution for food-deficit countries is to hold strategic reserves that can be 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 region, where imported wheat is the most significant component of 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 that this is the case for the Middle East and North Africa region. Nevertheless, the policy is more costly than a procyclical policy similar to food stamps that uses targeted transfers to directly offset high prices with a subsidy. 

JEL codes: F1, O13, Q11, Q18

High and volatile food prices and their consequences for the poor have revived concerns about food security and reinvigorated the debate over 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
over a decade, the real price of U.S. 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 declined sharply near 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 spike in food prices drove 44 million people into poverty (Ivanic and Martin 2008). Hardest hit were countries that imported most of their food and the poor, whose diets rely heavily on staple grains.

This is the case for many countries in the Middle East and North Africa (MENA) region. Diets there are highly dependent on wheat, which is largely imported (Table 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

| Table 1. Selected Wheat Statistics, Average 2005–07 |
|---------------------------------|-----------------|-----------------|-----------------|
| Net trade (Imports – Exports)   | Domestic consumption (thousands of tons) | 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                          | -536            | 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              | —               |
| RoW                            | -26,793         | 548,788         | -5              | —               |

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

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.
46 percent. Consequently, spikes in international wheat prices create hardships for the region’s poor and strain the resources of the public and private institutions that constitute 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.

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 presenting an agenda for the French presidency of the G20, suggested that subsidized storage might be a means 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). Moreover, in a Financial Times Op-Ed piece, former World Bank President Robert Zoellick urged the establishment of small, strategic food reserves in disaster-prone areas (Zoellick 2011). The build up of strategic reserves is also a key topic in MENA (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. In recent decades, MENA countries have increased their grain storage capacities, and wheat stocks have grown along with populations and demand. Precautionary policies also led to an increase in the stock-to-use ratio, concentrating a greater share of global stocks in the region. From negligible levels in 1970, the region held over 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 in 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 given the 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. Although 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 offshore price disturbances, the strategy has positive spillover effects, reducing global price variability rather than increasing it. However, the strategy will sometimes fail, when large or 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 procyclical relief program that targets up to 40 percent of the population is a less expensive alternative.

I. Background

Poverty is at the core of the region’s concerns about food security. About one-quarter of the population of 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 share 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 at 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 land 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 nearly 64 percent over the next 20 years (World Bank 2009).

When price shocks occur, governments often intervene. In MENA, the interventions take 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, government capacity 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 countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates) have ample budgetary resources to absorb higher costs despite being entirely dependent on 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 capacity to absorb sustained higher prices, although their higher domestic production levels help to cushion price shocks.

Despite the preponderance of consumer subsidies, the evidence suggests that international food price shocks are transmitted to domestic food prices throughout the region to various degrees (World Bank 2011b). Over the 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 in 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 in the West Bank and Gaza, accounting for more than 50 percent of food inflation, followed by Egypt, Djibouti, and the United Arab Emirates (over 40 percent of food inflation). The pass through is smaller but 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 Gulf Cooperation Council countries other than the 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 semipublic 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 above, 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 capacities. When the plans are fully implemented, agencies in those countries as well as 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 expansions in Jordan, Algeria, Tunisia, and Morocco will increase capacities in those countries to more than six months of consumption.

Although MENA countries differ with respect to the management of wheat supply chains, supply chain costs are generally high relative to the costs in benchmark countries. This is true even though the dry climates of MENA countries 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 import supply are also costly 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 that are 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 address high and volatile wheat prices. But before proceeding, it is worth noting that policy changes and public investments could also be brought to bear to address high supply chain costs. In particular, the funds 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.

II. 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 perceived as an exacerbating factor during the Great Depression. Consequently, commodity stabilization schemes and commodity-based currency rules were promoted by economists as diverse as Keynes (1938) and Hayek (1943). Subsequently, 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 components, 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, and 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 10 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 fully hedged in financial markets (Wright 1979; Wright and Williams 1982, 1988; Larson and Coleman 1993). Other writers noted that selecting 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 spectacularly, 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 theoretical benefits of stabilization were low on average and that the policies themselves were difficult to manage, a separate literature emerged showing that the 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. With respect to policy, this strand of the literature often promoted instruments designed to mitigate the harsh consequences of commodity price volatility rather than instruments meant to change the distribution of prices.

When once-stable crop prices spiked in 2008, price stability and poverty were again linked in the minds of policy makers as prices pushed the near poor into poverty. In response, governments intervened in markets, and price stabilization policies received renewed interest (Brinkman et al. 2010; Wodon and Zaman
The speed with which food exporters raised export taxes or banned exports in response to rising prices encouraged food importers to reconsider policies that would maintain 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. This omission leaves a knowledge gap for policy makers because other forms of investment can be viewed as complete or partial substitutes for 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 reduce transaction costs and average consumer prices.

III. 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). 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. This is because when stocks are low, it becomes more likely that production shortfalls will be rationed through high prices rather than buffered through stock drawdowns.

A key feature of this class of models, including the model presented here, is the need to form a rational set of numerical conditional price expectations to value carryover inventories and future production. Specifically, the model employs 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. Using these as a baseline, policies are introduced that are designed 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 means of evaluating the effects of strategic storage rules on price and consumption levels and volatility.

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 Williams 1982), convenience yields (Makki, Tweeten, and Miranda 1996), and risk premia (Larson 2007) are sufficient to generate this feature.
To make the numerical 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 above, countries in the region pursue similar policies, and the 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 illicit 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, in turn, are primarily managed by parastatal agencies. Because this share is large, the set of similar policies has an aggregate effect on global markets. By collapsing the numerous 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 similar policies implemented by countries in the region is a key innovation of the model. We also abstract from the technical and political economy obstacles to the implementation of the policy that we simulate.

It is worth noting that trade corridors remain available during our simulations despite the constraints on the capacity to restock strategic stores. This feature sidesteps a concern occasionally voiced by policy makers that trade corridors will shut down. Still, although it is possible to imagine scenarios in which governments have the capacity to distribute strategic stores of wheat but import supply chains are severed, real world instances have been few in recent times and brief in duration. 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 former. 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 $i \in \{\text{MENA, RoW}\}$ is given by a downward sloping function of the current price:

$$D^i(P^i_t) = a^i - b^iP^i_t$$

(1)

where $P^i_t$ is the price of wheat in period $t$ and region $i$.

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).
In each region, there is a representative storing agent that acts competitively and incurs the following cost for storing an amount \( S_i^t \) from period \( t \) until \( t + 1 \):

\[
K(S_i^t) = (1 + r)(kS_i^t + P_i^tS_i^t)
\]

(2)

where \( k \geq 0 \) is the net unit cost of physical storage services and \( r \) 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:

\[
S_i^t \geq 0 \perp P_i^t + k - E_tP_{t+1}^i/(1 + r) \geq 0
\]

(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 numerical model.

Production is uncertain in the model. Representative producers make their production decisions and pay for inputs one period before bringing output to market. We represent that choice, made in period \( t \), as planned production, \( H_i^t \). Actual and realized production differ by a multiplicative, exogenous disturbance term, \( e_{t+1}^i \), such that stochastic revenue is defined as \( P_{t+1}^iH_i^t e_{t+1}^i \). The producer’s decision is based on information and input prices in period \( t \) and can be written as

\[
\max_{H_i^t} E_t(P_{t+1}^iH_i^t e_{t+1}^i)/(1 + r) - \Psi^i(H_i^t)
\]

(4)

where \( e_t^i \) is normally distributed with a mean of 1 and a variance of \( \sigma_e^2 \); \( \Psi^i(H_i^t) \) is the production cost corresponding to the planned production. The solution to this problem is the following equation:

\[
E_t(P_{t+1}^i e_{t+1}^i)/(1 + r) = \Psi^t(H_i^t).
\]

(5)

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

6. The “perp” notation (\( \perp \)) used in the complementarity condition means that the expressions on either side of the sign are orthogonal; hence, if one equation holds as a strict inequality, the other side holds as a strict equality.
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:

\[ X_i^j \geq 0 \per P_i^j + \theta \geq P_i^j \text{ for } j \neq i \]  

(6)

where \( X_i^j \) is the export from region \( i \) and \( \theta \) 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 that they do not depend on the direction of trade.\(^7\) Hence, prices in MENA fall within a moving band that is defined by the RoW price and trade costs:

\[ P_j^i - \theta \leq P_i^j \leq P_i^j + \theta \text{ for } j \neq i. \]  

(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, \( H_{t-1}^i \); and the period shock, \( \varepsilon_t^i \). The last two variables determine actual production, and all three variables can be combined in one state variable, private availability, \( A_i^t \), the sum of production and private carryover:

\[ A_i^t = S_{t-1}^i + H_{t-1}^i \varepsilon_t^i. \]  

(8)

Hence, market equilibrium can be written as

\[ A_i^j + X_i^j = D^j(P^i_t) + S_i^j + X_i^j \text{ for } j \neq i. \]  

(9)

To summarize, the numerical problem has two state variables, \( \{A_i^{MENA}, A_i^{RoW}\} \), and eight response variables, \( \{P_i^t, S_i^t, H_i^t, X_i^t\} \), for \( i \in \{\text{MENA, RoW}\} \). Solutions follow a dynamic path since stocks are carried over from one period to the next.

**Calibrating the Model and Obtaining a Numerical Solution**

The parameters for the model are selected such that, at the nonstochastic 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 accounting for approximately 47 percent of its consumption. To calibrate the steady-state prices, we decided not to rely on 2011 values, which, as discussed above, are high by historical standards, since it is unlikely that the steady state is associated with extreme values. Instead, we calibrate the RoW price at \$176/ton, the average U.S. export price in

---

\(^7\) In practice, the MENA region does not export wheat, so the assumption of symmetric trade costs is innocuous.
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 the beginning of the decade. 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).

Selecting appropriate elasticities is a challenge given the large variation in the 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 we assume the demand elasticity to be equal to –0.12, which is toward the lower end of the range of commonly used elasticities. We consider a

### Table 2. Model Calibration Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Economic interpretation</th>
<th>MENA</th>
<th>RoW</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a^i )</td>
<td>Intercept of demand curve</td>
<td>84.336</td>
<td>664.048</td>
</tr>
<tr>
<td>( b^i )</td>
<td>Slope of demand curve</td>
<td>0.043</td>
<td>0.404</td>
</tr>
<tr>
<td>( c^i )</td>
<td>Intercept of marginal cost function</td>
<td>–805.905</td>
<td>–670.476</td>
</tr>
<tr>
<td>( d^i )</td>
<td>Slope of marginal cost function</td>
<td>25.059</td>
<td>1.335</td>
</tr>
<tr>
<td>( \text{Std}(\varepsilon^i) )</td>
<td>Standard deviation of production shocks</td>
<td>0.070</td>
<td>0.030</td>
</tr>
<tr>
<td>( r )</td>
<td>Interest rate (%)</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>( k )</td>
<td>Physical storage cost ($/ton)</td>
<td>22.40</td>
<td></td>
</tr>
<tr>
<td>( \theta )</td>
<td>Trade cost ($/ton)</td>
<td>35.55</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calibration target at steady state</th>
<th>MENA</th>
<th>RoW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption (millions of tons)</td>
<td>75.30</td>
<td>592.90</td>
</tr>
<tr>
<td>Production (millions of tons)</td>
<td>40.20</td>
<td>628.00</td>
</tr>
<tr>
<td>Price ($/ton)</td>
<td>211.55</td>
<td>176.00</td>
</tr>
<tr>
<td>Demand elasticity</td>
<td>–0.12</td>
<td></td>
</tr>
<tr>
<td>Supply elasticity</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coefficient of variation (%)</th>
<th>Simulated MENA</th>
<th>RoW</th>
<th>Observed MENA</th>
<th>RoW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>16.36</td>
<td>19.63</td>
<td>—</td>
<td>17.85</td>
</tr>
<tr>
<td>Exports</td>
<td>—</td>
<td>8.58</td>
<td>—</td>
<td>10.61</td>
</tr>
<tr>
<td>Demand</td>
<td>1.98</td>
<td>2.38</td>
<td>1.16</td>
<td>1.68</td>
</tr>
<tr>
<td>Production</td>
<td>7.01</td>
<td>3.04</td>
<td>7.54</td>
<td>3.46</td>
</tr>
</tbody>
</table>

Notes: Consumption, production, and price in RoW targets are determined as the trend values in 2011 after applying a Holdrick-Prescott filter (smoothing parameter of 400) on the underlying data. RoW consumption is adjusted to ensure global market equilibrium. The 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.

Source: Consumption and production data are from USDA (2011), and price data are from World Bank (2011a).
supply elasticity of 0.2, in line with commonly used supply elasticities for wheat. The cost function is assumed to be quadratic, making the marginal cost function linear. We express the marginal cost function as

$$\Psi^i \left( H_i^t \right) = c^i + d^i H_i^t .$$

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

We specify two sets of uncorrelated supply shocks, $e^i \sim N (1, \sigma_i^2)$. On the basis of historical production data, we derive an estimated distribution of supply shocks where production is more volatile in MENA than in the RoW. 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).

The rational expectations storage model lacks a closed-form solution so solutions must be approximated numerically. The algorithm that 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 upon which the model randomly draws 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 to test the validity of the aggregate consequences of our ex ante parameter selections. With this background, the simulated and historical coefficients of variation are reported in the bottom panel of table 2. As the table makes clear, the historical and simulated distributions are of similar orders of magnitude.

Before moving to a discussion of alternative policies, two points should be made regarding the 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 50 years.

The second point has to do with speculative storage—that is, storage 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 MENA.

Strategic Storage

In this section, we describe a regional cooperative strategy in which 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 such as 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 effects associated with government storage displacing private 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 interrelated components are needed to fully define the public intervention. The first concerns 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 stocks are prone to failure because they set out to defend unrealistic price goals. Moreover, even when goals are set reasonably, inventories are depleted when rare but eventual combinations of events occur, such as consecutive bad harvests. With this in mind, we have chosen a conservative strategic reserve objective for our simulation. Using the benchmark model, we simulated the range of MENA price

10. This 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).
outcomes and, from the resulting distribution of prices, selected 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. By choosing to intervene at the 90th percentile, the policy insures that interventions will be rare. Moreover, 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, that 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. In other words, 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 to consider 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 build up of stocks over a longer time period and diversifies price risk.

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

\[ 0 \leq S_t^G \leq \bar{S}_t^G (S_{t-1}^G) \perp p_t^{MENA} - P^C \quad (11) \]

where \( S_t^G \) is the public storage level in MENA, \( P^C \) is the price ceiling, and \( \bar{S}_t^G (S_{t-1}^G) \) 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 must 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:

\[ S_{t-1}^G + A_t^{MENA} + X_t^{RoW} = D_t^{MENA} (p_t^{MENA}) + S_t^{MENA} + S_t^G. \quad (12) \]

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.
As discussed previously, 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 the MENA export equation (equation (6) for \( i = \text{MENA} \) in the benchmark model) and MENA exports from the RoW market equilibrium.

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

\[
S^G(S_{t-1}^G) = \min\left( S^G, \alpha S^G + S_{t-1}^G \right).
\]

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, \( \{ A_t^{\text{MENA}}, A_t^{\text{RoW}}, S_t^G \} \), and eight response variables, \( \{ P_t, S_t, H_t, X_t^{\text{RoW}}, S_t^G \} \), for \( i \in \{ \text{MENA}, \text{RoW} \} \).12

IV. SIMULATION OUTCOMES

As previously discussed, the intervention price is set high and is designed to protect against the highest 10 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 to 1.5 years of steady-state imports. For a given starting point, the outcomes depend on the realized supply shocks, and probable outcomes only merge to an expected trajectory after simulating several possible sequences of shocks.

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 the domestic price and the target price is frequently small, and a partial release of stocks is sufficient to drive down both domestic and international prices. 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

12. 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.

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.
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. Ranges of targeted reserve levels are reported along the horizontal axes of the figure’s panels, and the variables of interest are reported on the vertical axes.

Turning first to the upper left-hand-side panel, the simulation results suggest that the strategic reserve can be effective in reducing 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 to 50 percent increases the robustness of the policy because 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 result of the model is that the strategic reserve policy, which is designed to protect domestic consumers, also reduces the volatility of prices in the RoW. Indeed, a comparison of the upper and lower portions of the first panel of figure 1 shows that because of trade, the CV of price in the RoW evolves in a similar manner as the CV in MENA. By design, there are periods when the stocks released under the strategy are sufficiently large 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 reestablished when the trigger is breached, but stocks are insufficient to insulate domestic consumers.

As discussed, an aggressive strategy of restocking reserves reduces the likelihood 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 additional reserves when international availability is tight and prices are high. Consequently, the relationship between the CV 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 reduce 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. Therefore, they generate small marginal reductions in price volatility.

Before proceeding to a discussion of program costs, two additional consequences of MENA’s adoption of a 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 trade volatility.\footnote{For non-oil exporters in the region, food imports can affect exchange rates and have 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.} 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 that we examine, a run on public reserves (as in Salant 1983) is unlikely since the intervention price is quite high. In the scenarios that we simulate, the level of global stock increases because of the policy, but this is accomplished partly at the expense of speculative storage. Moreover, in a strategic reserve program, private storage begins to accumulate stocks at much higher availability levels when the release of public stocks is less likely.

**Program Costs**

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

$$\left[1 - \frac{1}{1 + r}\right]E_0 \sum_{t=0}^{\infty} (1 + r)^{-t} \left[\left(\frac{S^G_{t} - P^MENA_{t}S^G_{t}}{C_0}\right) + k\right]$$

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 of 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 percent 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 on the restocking rate, the gains to increasing the target storage level flatten out and little is gained, even while program costs continue to rise in a linear fashion (figure 1). For example, a strategy that sets a reserve target of 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 to 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.
**Targeted Transfers**

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. In contrast 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 incurred when prices breach the targeted price.

Before continuing, it should be noted that there are alternative ways of structuring targeted food safety nets.\(^\text{15}\) There are also alternative ways to finance safety net programs, drawing on financial risk-management instruments, including options, weather insurance, and catastrophe bonds (Alderman and Haque 2006; Mahul and Ghesquiere 2007; Skees et al. 2005). However, for our purposes, cash-equivalent transfers, in which the program’s cost falls to the government, serve as a realistic, useful, and simple benchmark for the comparison of program costs.

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

\[
A_t^{\text{MENA}} + X_t^{\text{RoW}} = (1 - \lambda)D_t^{\text{MENA}}(P_t^{\text{MENA}}) + \lambda D_t^{\text{MENA}}(\min(P_t^{\text{MENA}}, P^C)) + S_t^{\text{MENA}} + X_t^{\text{MENA}}
\]

where \(\lambda\) represents the share of households covered by the policy. The costs associated with identifying and targeting qualifying households are excluded, even though the costs may be consequential. The cost of this policy is given by

\[
[1 - 1/(1 + r)]\lambda E_0 \sum_{t=0}^{\infty} (1 + r)^{-t} \left[ \max(P_t^{\text{MENA}} - P^C, 0) D_t^{\text{MENA}}(\min(P_t^{\text{MENA}}, P^C)) \right].
\]

The simulation results show that because the trigger price is at the 90th quantile, payouts occur infrequently. Moreover, because the program covers the thin tail

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15. Cash transfers are increasingly used in developing countries, in part because of new technologies that lower implementation costs (Ahmed 2005). However targeted and self-targeted food transfers are still frequently used. Moreover, there are reasons for preferring food transfers to income transfers when food markets perform poorly (del Ninno, Dorosh, and Subbarao 2007; Sabates-Wheeler and Devereux 2010; Cunha, De Giorgi, and Jayachandran 2011). Magen et al. (2009) explore transfer programs in the context of food crises.
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 result in average program costs of $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. 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 rate of 40 percent of the population were $3.78 billion—nearly 70 times average costs. However, this value was extreme, and 99 percent of the payouts were under $1.34 billion (about 25 times the 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 because the capacity to purchase additional food precludes the long-term consequences of even temporary periods of poverty and malnutrition. However, this also means that for the covered portion of the population, 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. Consequently, the program creates an added cost for most consumers because less adjustment in demand leads to greater price volatility, both in MENA and in the RoW. Quantitatively, the 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 percent, 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 results based on alternative assumptions about supply and demand elasticities and interest rates. The sensitivity analysis shows that these basic model assumptions 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 in which inventories are immediately replenished. These results are summarized in figure 2.

**Interest Rate.** We considered two interest rates, 3 and 8 percent, whereas 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 because a lower interest rate of 3 percent decreases the CV of price by less than one point. The policy effects are not sensitive to the interest rate; the results are simply translated with respect to the effect of the interest rate on volatility in the absence of a policy. In other words, the benchmark results are affected by interest assumptions, but the effects of the 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 than the 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. 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 because public stocks are rarely sold. Nonetheless, it should be noted 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 the supply elasticity are
limited. As expected, with lower (higher) supply elasticity, price volatility is higher (lower), but not substantially so; price volatility in the absence of 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 calibration of supply elasticity are on benchmark price volatility rather than the way price volatility declines as public stock targets are increased.

V. Conclusions

In this paper, we describe a rational expectations model of competitive storage and trade based on wheat markets for MENA and the RoW. 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 body of knowledge 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 show 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, procyclical transfer programs add slightly to price volatility. Transfer programs also rely on continuous trade, and while physical disruptions to trade are infrequent and brief, governments that rely on transfers rather than strategic stocks should have contingency 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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