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Market intermediaries, storage and policy reforms

Steve McCorriston[1] | **Donald MacLaren**[2]

[1]Economics Department, University of Exeter, Exeter, UK

[2]Economics Department, University of Melbourne, Melbourne, Australia

Correspondence
Steve McCorriston, Economics Department, University of Exeter, Exeter, UK.
Email: s.mccorriston@exeter.ac.uk

Abstract

Intermediaries play a crucial role in the functioning of agricultural and food markets in developing countries through linking production, imports and storage with consumption. We analyse how competition in the intermediary sector and alternative forms of intermediaries determine the incentives for storage and market outcomes more generally. We apply this framework to the Egyptian wheat sector as an illustrative case study, a country where food security is a priority, where both forms of intermediaries co-exist and undertake storage but where issues of reforms to the role of intermediaries have been raised. Through stochastic simulation, we analyse two changes in government policy: first, the effects of changing the policy instruments with both types of intermediaries undertaking storage; second, relating to market reforms where the private sector replaces the storage function of the parastatal. These issues have wider significance for addressing the interaction between food security and a wide range of policy reforms including de-regulation of parastatals in developing countries.

KEYWORDS

Egyptian wheat marketing, parastatals, policy, private market intermediaries, storage

JEL CLASSIFICATION

D02, D49, F12, L10, L32, L33, Q13

1 | INTRODUCTION

Intermediaries play a crucial role in the functioning of agricultural and food markets. In a recent survey Barrett et al. (2020) identified the need for more research on this issue, particularly with reference to developing and emerging economies. If intermediary markets were competitive and absent other market frictions, intermediaries would not impact on the distributional effects of government policy reforms. On the other hand, if the competitive assumption does not hold, then the presence of intermediaries will influence the extent to which consumers and producers

(often constituting the poorest sections of the population) will gain or lose from policy changes as well as affecting exchequer costs. In this context, we contribute to growing research on intermediaries in developing country agricultural and food markets. We do so from two perspectives.

First, noting that intermediaries in developing countries come in different forms, we compare market outcomes of private intermediaries and parastatals. This is an important issue from several perspectives. With reference to private firms in agricultural and food markets in developing countries, concerns arise with respect to the extent of competition in intermediary markets. This reality departs from the textbook assumption that intermediary markets are perfectly competitive. In a recent assessment of competition issues in agricultural and food markets in African countries, a World Bank review noted that the prices of 10 key staples, including bread and flour, were 24% higher than in the rest of the world, even after controlling for transportation costs, geography and other factors. It was concluded that, more generally, African countries have lower levels of competition than other countries around the world (World Bank, 2016). Bergazo and Nymen (2016) summarise some of the concerns associated with competition and poverty in developing countries. However, in many developing and emerging economies, parastatals—rather than private firms—continue to play a key role in the procurement, trade and distribution of agricultural and food products. The presence of parastatals is a crucial characteristic for understanding intermediary markets insofar as they involve the direct manipulation by governments of the intermediary market, either by bestowing monopoly/monopsony status on the parastatal or by the exclusion of private firms in certain marketing functions.[1] As we detail below, the issue of parastatals as intermediaries extends beyond the monopoly/monopsony status with which they are often associated.

Second, we allow intermediaries to store agricultural commodities. This is a relevant feature of many intermediary markets since such markets are characterised by the stochastic nature of production and prices and storage can play a role by ameliorating the effects of market volatility. However, the role of storage by intermediaries has been largely set aside in the literature on commodity storage and it has not featured in the recent line of research on intermediaries in developing country agricultural and food markets. Yet, storage is an important feature of markets particularly for staples and it is undertaken by intermediaries. In the example we outline below (relating to the bread market in Egypt), both the parastatal and private intermediary sectors store commodities. In the case of the marketing reforms in India, one element is to remove limits on how much private intermediaries are allowed to store.[2] In the extant literature, where the link between market structure and storage has been addressed, it has typically focused on the supply of storage (the agency responsible for storage is not responsible for procurement and/or distribution) and on the extremes of monopoly and competitive markets. The issue of competition between intermediaries and how alternative forms of intermediaries affect storage has not featured. Yet, in many developing and emerging economies, storage is an important aspect of agricultural and food supply chains and, as we show below, government policies either in the form of changing policy instruments or in marketing reforms (e.g., increasing the role of the private sector in storage activities) is an important feature in the overall assessment of government policies, the outcomes of which are influenced by, and also determine the incentives for, storage.

More generally, there is a literature documenting reforms to parastatals and state involvement in procurement though, in large part, it has lacked a theoretical framework (see, e.g.,

[1]This may include, for example, exclusive rights bestowed on the parastatal to export or import agricultural commodities or limits placed on storage by private firms.

[2]The recent marketing reforms in India attracted widespread attention, a key part of which centred on limiting the role of the state and increasing the role of private intermediaries in the supply chain in 'essential' commodity sectors. These marketing reforms related to three pieces of legislation: the Farmers' Produce and Commerce Bill (2020), the Farmers' Produce (Empowerment and Protection) Agreement of Price Assurance, Farm Services Bill (2020) and the Essential Commodities (Amendment) Bill (2020). Narayanan (2020) provides an overview of these reforms. Reflecting the strength of opposition by farmers to the proposed marketing reforms, at the time of writing, the Indian government announced it was abandoning the legislation.

Ganesh-Kumar et al., 2010; Rashid et al., 2008). In general terms, though the reform debate may be cast in terms of parastatal versus private sector, reforms in practice may be only partial in nature, where the private sector takes over some of the functions of the parastatal. As noted above, this was an aspect of the widely opposed marketing reforms in India. But the issue is more widespread and unlikely to diminish. Other examples where the state has control over domestic procurement and storage for key commodities to ensure food security include Indonesia and Middle East and North African (MENA) countries (see, Larson et al., 2014).[3] The challenge for research is to provide insights for a more informed debate in which the aspects of partial reforms to market structure can be addressed.[4]

We focus on the linkages between alternative forms of intermediaries, the role of storage and government reforms that promote food security, and a market structure in which private firms take over some of the functions of the parastatal. We begin by developing a framework where we highlight how the characterisation of the intermediary sector impacts on the levels of storage. We then extend the framework to take account of specific government policy instruments and market reforms that alter the role of the private sector. Though the issue of storage and the characterisation of the intermediary sector is generic, we are motivated by, and calibrate the model to, the bread market in Egypt. Food security is a politically sensitive issue in Egypt, a country in which the costs of supplying bread at subsidised prices has been shown to have a considerable impact on public finances, thereby making it a priority for reform (FAO, 2015).[5] In terms of investigating how the structure of the intermediary market (with storage undertaken by both the parastatal and private intermediaries) influences the outcomes of potential government reforms, the Egyptian bread market serves as an ideal illustrative case study for the theoretical framework we set out. Because we are exploring alternative potential reforms that interact with the structure of intermediary markets, we rely on calibrating the theoretical framework to provide the main insights that would arise for food security outcomes.

Specifically, the Egyptian wheat market is segmented into the processing of (*baladi*) bread, which is subsidised by the central government, and the bakery (*fino*) sector, which is not. Intermediaries characterise each segment of this market with public agencies functioning in the *baladi* bread segment and private firms in the *fino* segment. In each segment, intermediaries have storage facilities. We conduct a range of simulations relating to potential reforms of government policy in the bread market (e.g., using per unit consumer subsidies as an alternative to fixed consumer prices to ensure access to cheaper staples) as well as simulations that give a greater role to the private sector in the segment where the government agency currently functions (e.g., private intermediaries taking over the storage function of the parastatal).

The paper is organised as follows. In Section 2 we relate our contribution to the relevant literature. In Section 3 we detail the theoretical framework that compares procurement, storage and distribution where the intermediary sector is characterised by either private profit maximising firms or a weighted-welfare maximising parastatal. We calibrate the model to the Egyptian wheat sector, the background to which is given in Section 4. Details of the calibration and the treatment of stochastic variables are provided in the Appendix S1. We explain in Section 4 how the theoretical model is amended to accommodate the specific features of the Egyptian wheat market as well as the policy instruments employed by the Egyptian government. We show in Section 5 how changes in market structure may affect the outcomes from potential policy reforms. In Section 6 we summarise and conclude.

[3]Details on the organisation of policies to promote food security across several countries is provided in Alderman et al. (2018).
[4]In Larson et al. (2014), although they note the existence of parastatals in procurement, storage and distribution across MENA countries, their existence is not analysed in their modelling.
[5]Food security in Egypt is highlighted in the current context where over half of Egypt's wheat imports are sourced from Russia and Ukraine.

2 | RELATED LITERATURE

The industrial organisation of agricultural and food markets in developing and emerging economies is complex and, in many countries, is undergoing significant change. These markets do not fit with the standard textbook model where intermediaries are absent or are assumed perfectly competitive. Specifically, high levels of market concentration characterise many sectors (see McCorriston, 2015; Porto et al., 2011). There is the increasing growth of agribusiness and the use of contracting as a means for small producers to access export markets (Macchiavello & Marjaria, 2019; Swinnen et al., 2015). There is an increasing presence of retail food chains (Reardon, 2015). On the supply side, there are large numbers of small producers co-existing with a small number of large commercial farms. De-regulation of parastatals and/or enhancing the role of the private sector has been on the reform agenda of many countries (Barrett & Mutambatsere, 2008). These issues give rise to a number of concerns regarding the distributional effects from trade reform, the impact of retail chains on consumers and the outcome of deregulation on producer welfare. Research addressing the impact of the industrial organisation of food and agricultural markets in developing countries is an important research issue (Barrett et al., 2020).

From the extant literature, we have an indication of why the intermediary market matters. Sexton et al. (2007) show that, in the context of a developing country exporter faced with both seller and buyer power in the agri-food value chain, the gains to farmers who have increased market access to developed country markets are considerably less than would be the case if the stages of the value chain were competitive. Similar insights arise with respect to Porto et al.'s (2011) assessment of the gains from exporting across a number of sectors for selected African countries. If the downstream intermediary sector were competitive, the gains to farmers would be greater compared with those in the imperfectly competitive case. Atkin and Donaldson (2015), using food price data for Ethiopia and Nigeria, show that the gains to consumers are determined by the presence of intermediaries. More broadly, Bergazo and Nymen (2016) provide a summary of the wider concerns associated with competition issues and poverty in developing countries.

Parastatals are also an important aspect of the structure of intermediary sectors. Less formal attention has been given to parastatals and the different forms in which they come. McCorriston and MacLaren (2007, 2016) show that the issue of parastatals is not confined to their potential monopoly/monopsony status; other issues matter too. These include the nature of the parastatal's pay-off function, the exclusive rights that apply to the parastatal's ability to function in certain segments of the market; the coexistence with the private sector; and the relative (in)efficiency of the parastatal compared with private firms. Moreover, government reforms have altered the structure of the intermediary market in many developing countries through deregulation. For example, Ganesh-Kumar et al. (2010) highlight market reforms of parastatals in Asian countries and Jayne et al. (2006) highlight similar issues with respect to African countries; McCorriston and MacLaren (2016) show that deregulation does not necessarily improve food security; Cadot et al. (2009) assess the outcome of the disbandment of the vanilla state marketing board in Madagascar and report a positive outcome for producers; Dhingra and Tenreyro (2020) focus on the growth of agribusiness following the liberalisation of the state in Kenya and show how those small producers who were tied with agribusiness experienced lower incomes compared with those who engaged with traditional traders.

Research addressing competition and alternative forms of intermediaries has been primarily addressed in a static environment, yet agricultural markets, both domestic and international, are characterised by volatility. Storage is also a characteristic of these markets though the issue of storage and market structure has been largely unexplored. Our focus in the framework we present below is on the incentive of alternative forms of intermediaries to store commodities in an importing country setting where the government employs additional policy instruments to promote food security. This motivation for storage is distinct from storage as part of buffer

stock schemes to manage price bands or for strategic reserves.[6] Of the limited research on market structure and storage that does exist, a range of factors that matter in determining the links between competition and storage have been highlighted. These include whether monopoly power relates to storage only (Williams & Wright, 1991) and whether producers also have market power (see McLaren, 1999; Newbery, 1984; Thille, 2006). These alternative approaches give rise to some ambiguity on whether storage and price volatility is higher under monopoly or competitive markets. Thille (2006) also shows that the effects of storage on price volatility depend on the source of shocks in a specific market.[7] Common to research addressing the links between market structure and storage is the focus on closed economy settings (see, e.g., Bieri & Schmitz, 1974, for an early analysis of the effects of market structure on storage and price instability in a closed economy).[8] In open economy contexts, rest-of-the-world supply fluctuations that impact world market prices are also a source of domestic price volatility that storage can help ameliorate (Gouel & Jean, 2015) though they do not address the issue of domestic market structure. Larson et al. (2014), who also address food insecurity, price volatility and storage with a theoretical model applied in the MENA context, note the existence of parastatals in procurement, storage and distribution but set aside these issues in their theoretical framework.[9]

3 | THEORETICAL FRAMEWORK

Here, we set out the main features of an open economy commodity market that is characterised domestically by intermediaries and storage. The intermediaries are taken to be either private firms that maximise profits or a parastatal that seeks to maximise a weighted social welfare function. Our illustrative country is always less than self-sufficient. This assumption is made partly to reflect the reality in several developing countries and partly to simplify the analysis by preventing the country from switching between importing and exporting or being at times fully self-sufficient. The cost of imports for consumption and storage depends on the exogenously given world market price. Intermediaries, therefore, cannot exercise buyer power in procurement from domestic production or imports, nor can they price discriminate across these sources of procurement. Although world prices determine procurement costs, consumer prices also depend on the structure of the intermediary market. For example, if there was a single intermediary that maximised profit, it would have a monopoly mark-up and consumers would pay prices in excess of world market prices. On the other hand, if the intermediary had a bias towards consumers, then it would procure more and reduce the consumer price (though potentially still in excess of the world market price) compared with a profit-maximising intermediary.

The essential features of the model are developed in the following example, which, in contrast with the extant literature on storage in an open economy, is intended to show that intermediaries may find it profitable to procure for storage. Let the private intermediaries be n identical Cournot firms. They are responsible for domestic procurement, for imports, for storage and for distribution to consumers. The domestically produced and imported commodities are homogeneous. This is one justification for using the Cournot assumption. Domestic production is stochastic, it is consumed but not stored, and it is undertaken by a large number of atomistic risk-neutral

[6]Coverage of these issues can be found in Williams and Wright (1991).
[7]The industrial organisation literature focuses on the strategic use of inventories in determining interactions between limited numbers of firms (see, e.g., Avram, 1984; Allaz, 1991; Rotemberg & Saloner, 1989) though these insights are less pertinent to the price volatility that is induced by the random harvests which typify many commodity markets.
[8]Newbery (1984) is an exception where storage relates to a setting where commodity exporters can exercise control in specific markets.
[9]Our focus here is on the interaction between market structure, parastatals and storage. Other aspects of parastatals have also been addressed, most notably, the role of rent-seeking (see Fulton & Reynolds, 2015). This issue also ties in with broader concerns about politically connected organisations that may be a feature of the way in which parastatals function. For a general discussion see Faccio (2006) and Choi and Thum (2009).

producers. There is a one-period lag between production decisions and realisations of production. Thus, the market period inverse supply function is vertical at realised production.

The world price has a stationary probability distribution with given moments. Procurement by the intermediaries from both sources takes place at the world price. We assume for the moment that there are no storage losses. The inverse consumer demand function is stationary and deterministic. These assumptions allow us to focus on the implications of the structure of the intermediary sector on outcomes for consumption, storage and consumer prices, that is, on food security. Of course, governments can also use other policy instruments to promote food security; we address this issue in Section 4.

3.1 | Consumers

Consumers are risk-neutral with an inverse demand function given by:

$$p_t = \alpha - \gamma C_t \tag{1}$$

where, at time t, p_t is the consumer price; C_t is the quantity consumed; $\alpha > \max p_t^w > 0$ and $\gamma > 0$ are parameters; and $\max p_t^w$ is the upper support for the probability distribution of the world price.[10]

3.2 | Domestic production

The representative jth risk-neutral, atomistic domestic producer of the commodity makes planning decisions at time $t-1$ for production which is realised at time t.[11] The quantities of production planned (h_{t-1}^j), and realised ($h_{t-1}^j\left(1+\varepsilon_t^j\right)$), are assumed to differ because of the effects of weather and the incidence of pests and diseases. These effects are represented by the term ε_t^j. It is assumed to be an i.i.d. stochastic term with mean zero and constant variance. In addition, it is defined on $-1 \le \varepsilon_t^j \le \overline{\varepsilon}$ where $\overline{\varepsilon}$ is such as to ensure that the country remains less than self-sufficient taking into account stock carry-in.

The producer's expected profit function is determined by discounted expected revenue and by the total costs of production:

$$E_{t-1}\pi_t^j = \beta E_{t-1} p_t^w\left(1+\varepsilon_t^j\right) - \phi\left(h_{t-1}^j\right)$$

where E_{t-1} is the expectations operator conditional on the information available at time $t-1$; $\beta = 1/(1+\rho)$ is the discount factor when the interest rate is ρ; p_t^w is the procurement (i.e., import) price received by producers; and ϕ is the total cost function with all costs assumed to be incurred at $t-1$.

Maximisation of this function with respect to planned production, h_{t-1}^j, gives:

$$\beta E_{t-1} p_t^w\left(1+\varepsilon_t^j\right) = \phi'\left(h_{t-1}^j\right)$$

[10]The linear functional form will influence the pass-through of world market prices to consumers and the change in the mark-up in the intermediary sector. As long as the demand function is not too convex, there will be imperfect pass-through and mark-up adjustment due to the change in world market prices. As such, the linear functional form has the advantage of providing the basis for the insights on the interaction between distribution and storage but should be consistent with the impact on alternative sources of profits with other functional forms.

[11]If the producer were risk-averse, planned production would be smaller than if risk neutral but this would not change the basics of the model because the intermediaries would import more to satisfy consumption and stocks.

The producer sets the marginal cost of production equal to the discounted value of expected unit revenue. Aggregate planned production is then $h^j_{t-1} = \sum_j h^j_{t-1}$. Given the one-period production lag and the stationarity of the world price distribution, the market supply function is perfectly price inelastic at time t, and planned production, h_{t-1}, is the constant h for all t.

3.3 | Private intermediaries

The ith intermediary has the profit function:

$$\pi^i_t = \left(p_t - p^w_t\right)c^i_t + \left[\beta E_t p_{t+1} - p^w_t - K\right]s^i_t \tag{2}$$

where c^i_t is its sales to consumers comprising procurement from domestic production (h_t), imports (m_t) and stock carry-in (s^i_{t-1}), that is, $c^i_t = h^i_t + m^i_t + s^i_{t-1}$; p^w_t is the exogenous world price which is the procurement price for both domestic production and imports; β is the discount factor; K is the unit cost of storage for one period; and s^i_t is stock carry-out. For a given level of consumption, with domestic production and stock carry-in both predetermined, imports are the residual procurement required to satisfy optimal consumption.

Maximisation of Equation (2) with respect to consumption (sales) gives:

$$c^{i*}_t = \frac{\alpha - p^w_t}{\gamma(n+1)} \tag{3}$$

and substitution of $nc^{i*}_t = C^*_t$ into Equation (1) gives the corresponding consumer price:

$$p^*_t = \frac{\alpha + np^w_t}{(n+1)} \tag{4}$$

For a given n, both optimal sales and the consumer price are functions of the current world price only. The effect of n on optimal sales by the ith firm is found by totally differentiating the first-order condition, which gives $\frac{dc^{i*}_t}{dn} = -\frac{c^i_t}{(n+1)} < 0$. The effect of the number of firms on aggregate consumption is given by $\frac{dC^{i*}_t}{dn} = \frac{C_t}{(n+1)} > 0$. As we show below, an important implication of the latter result for storage is that as the consumer price decreases with increasing n, the profitability of storage is also reduced.

Maximisation of Equation (2) with respect to stock carry-out gives:

$$s^{i*}_t = \begin{cases} \frac{1}{\gamma}\left[E_t p_{t+1} - \left(p^w_t + K\right)/\beta\right], s^{i*}_t > 0 \\ 0, \text{otherwise} \end{cases} \tag{5}$$

Taking the expectation of Equation (4) advanced by one time period, the firm's optimal carry-out can be rewritten as:

$$s^{i*}_t = \begin{cases} \frac{1}{\gamma}\left[\frac{\alpha + nE_t p^w_{t+1}}{(n+1)} - \frac{p^w_t + K}{\beta}\right], s^{i*}_t > 0 \\ 0, \text{otherwise} \end{cases} \tag{6}$$

The first term in the bracket is constant for a given n, while the second term varies according to the realised value of the world price. Thus, optimal stock carry-out depends negatively

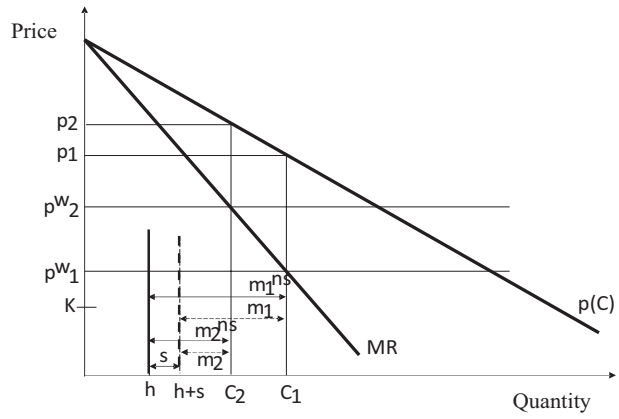

FIGURE 1 Storage and imports with varying world prices.

on increases of n, of p_t^w, of K and on decreases of β. The maximum value of the import price at which stock carry-out will be positive can be obtained from rearranging Equation (6): $p_t^w < \beta\left(\alpha + nE_t p_{t+1}^w\right)/(n+1) - K$. It is a decreasing function of the number of firms for given K and β. Stock carry-out, just as with consumption, is a function of the world price only. It is not dependent on consumption or on consumer prices or on the realised world price at time $t+1$.[12] Optimal stock carry-out for the intermediaries in aggregate is $ns_t^{i*} = S_t^*$.

Totally differentiating the first-order condition for Equation (6) gives the sign of the change in stock procurement by the ith firm as n increases. It is given by $\frac{ds_t^{i*}}{dn} = \frac{-\left(\alpha - E_t p_{t+1}^w\right)}{\gamma(n+1)^2} < 0$, and the change in aggregate procurement is: $\frac{dS_t^*}{dn} = \frac{1}{\gamma}\left[\frac{\alpha + \left(2n+n^2\right)E_t p_{t+1}^w}{\gamma(n+1)^2} - \frac{p_t^w + K}{\beta}\right]$, the sign of which is ambiguous.

A summary of the model is shown in Figure 1 for $n=1$ in which the world price takes one of two values with equal probability. Positive storage has two implications: first, it provides a source of profits in addition to those derived from sales to consumers; and second, it displaces an equal quantity of imports, thereby reducing the cost of procuring imports when the world price is p_2^w.

Suppose at time t there is no stock carry-in from time $t-1$ because at time $t-1$, $p_{t-1}^w + K > \beta E_{t-1} p_t$ (from Equation 5). Then, if the world price at time t is p_2^w, consumption is $C_2 = h + m_2^{ns}$, where h is realised production. The consumer price is p_2 and profit is $\pi_2^{ns} = p_2 C_2 - p_2^w\left(h + m_2^{ns}\right)$. On the other hand, if the world price is p_1^w, consumption is $C_1 = h + m_1^{ns}$ at the consumer price of p_1 and profit is $\pi_1^{ns} = p_1 C_1 - p_1^w\left(h + m_1^{ns}\right)$. Then expected profit at time t is $\pi^{ns} = 0.5\left(\pi_1^{ns} + \pi_2^{ns}\right)$. Now suppose instead that there is stock carry-in from time $t-1$. The cost of procurement for this stock was incurred at time $t-1$. If the world price is p_2^w, then consumption is $C_2 = h + m_2 + s$, the consumer price is p_2, there is no carry-out stock because $p_2^w + K > \beta E_t p_{t+1}$, and profit is $\pi_2 = p_2 C_2 - p_2^w(h + m_2)$. In the figure, the value of K was chosen to ensure that stock carry-out is profitable at only the lower of the two world prices. If the world price is p_1^w, then consumption is $C_1 = h + m_1 + s$, the consumer price is p_1, there will be stock carry-out of s at a cost of $\left(p_1^w + K\right)s$, and profit of $\pi_1 = p_1 C_1 - p_1^w(h + m_1) - \left(p_1^w + K\right)s$. Expected profit is then $\pi = 0.5(\pi_1 + \pi_2)$. To

[12]This characteristic of the model differentiates it from many storage models, for example those involving a large country in which the world price is endogenous, and those models specified in a closed economy. In both cases, backward induction is used to determine the solution. Such a solution procedure is not required in the framework here because optimal stock carry-out depends only on the static mean of the world price distribution.

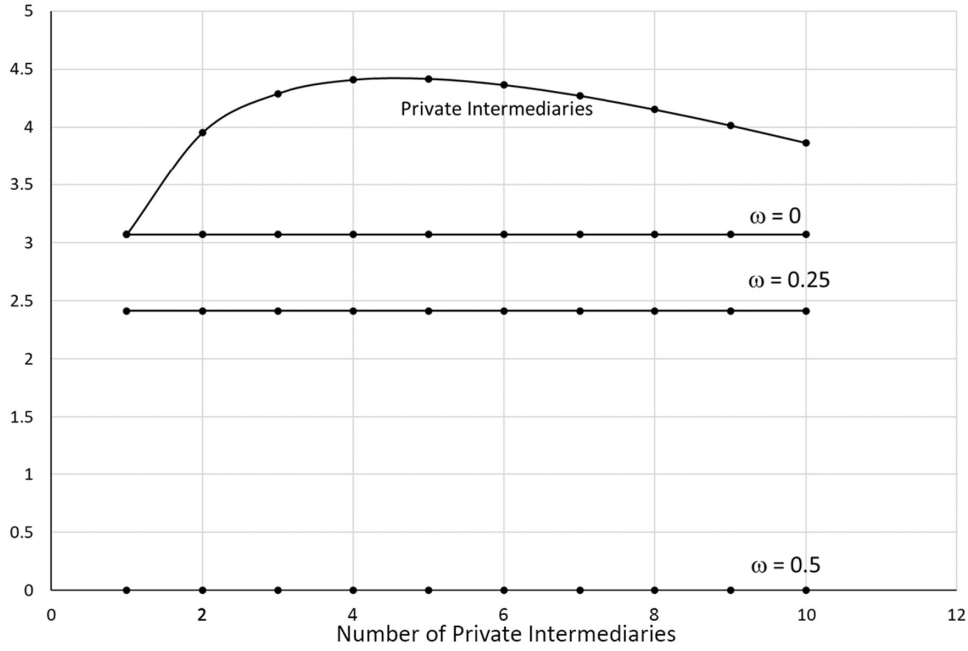

FIGURE 2 Optimal storage with private intermediaries and a parastatal (mmt).

determine whether storage is profitable, take the difference between the two expected profits. Noting that $m_j^{ns} = m_j + s$, for $j = 1, 2$, then $(\pi - \pi^{ns}) = 0.5\left(p_2^w - K\right)s > 0$. Therefore, if the difference between the higher of the two import prices and the carrying cost of storage is positive, then storage for the private intermediary is expected to be profitable.

The figure has been drawn for the monopoly case ($n = 1$). As the number of firms increases, the perceived marginal revenue function rotates counter-clockwise towards the demand function. As it does so, the optimal level of consumption increases and the consumer price decreases as will. With the expected price at $t+1$ diminishing, the optimal amount to store also diminishes (see Equation 5). The effect on the optimal size of the individual firm's storage is thus unambiguous. As was shown above, the effect this increase in n has on the size of aggregate storage, S^*, is also ambiguous. The implication is that the size of S as drawn in the figure may or may not decrease as the perceived marginal revenue function rotates. It may not even be monotonic, as shown below (Figure 2).

3.4 | Parastatal

Consider now the alternative market structure, one in which there is a risk-neutral parastatal in place of private intermediaries. For the moment, we assume that the parastatal has the same cost structure as the private intermediaries, an assumption that is relaxed in Section 4. Following McCorriston and MacLaren (2007, 2016), we specify the parastatal's payoff function as a politically weighted social welfare function which reflects the bias of government policy towards consumers only[13]:

$$W_t = \omega CS_t + (1 - \omega)\pi_t \tag{2}$$

[13]The parastatal cannot affect producer surplus unless it were to choose a procurement price that is different from the world price.

where, at time t, CS_t is consumer surplus, conventionally defined; π_t is profit as defined in Equation (2), except that the i superscript is no longer relevant; and ω is the political weight chosen by government that is attached to consumer surplus, with $0 \leq \omega \leq \overline{\omega}$. The restriction on the upper value of the policy weight is to ensure that the parastatal continues to put some weight on profit. At the same time, if food security is an objective, then having some consumer bias will ensure that greater consumption at more affordable prices is achieved compared with the situation in which $\omega = 0$.

The parastatal maximises its payoff function with respect to sales to consumers and to stock carry-out. The maximisation of Equation (2') with respect to C_t gives:

$$C_t^* = \frac{(1-\omega)\left(\alpha - p_t^w\right)}{\gamma(2-3\omega)}, \text{for } 0 \leq \omega < 2/3 \tag{3}$$

and substitution into Equation (1) gives the corresponding equilibrium price:

$$p_t^* = \frac{(1-2\omega)\alpha + (1-\omega)p_t^w}{(2-3\omega)} \tag{4}$$

Thus, optimal consumption and price depend on the world price and on the size of the bias towards consumers. If $\omega = 0$ and $n = 1$, then Equations (3) and (3') would be identical, as would Equations (4) and (4'). In other words, a private monopoly and a parastatal with no consumer bias represent identical market structures in terms of outcomes.

Optimal consumption needs to be positively related to this weight if the parastatal's objective of enhanced food security is to be achieved, given that it cannot affect domestic production. Totally differentiating the first-order condition gives: $\frac{dC_t^*}{d\omega} = \frac{\alpha - p_t^w}{\gamma(2-3\omega)^2} > 0$. A consumer-biased parastatal will indeed create greater food security than a monopoly but, in the absence of simulation, we do not know whether an n-firm oligopoly will generate even greater consumption than that of a consumer-biased parastatal. We explore this issue below.

Storage is obtained by maximising Equation (2') with respect to S_t. The result is:

$$S_t^* = \begin{cases} \frac{1}{\gamma}\left[\frac{(1-2\omega)\alpha + (1-\omega)E_t p_{t+1}^w}{(2-3\omega)} - \frac{p_t^w + K}{\beta}\right], S_t^* > 0 \\ 0, \text{otherwise} \end{cases} \tag{6}$$

Again, with $\omega = 0$ and $n = 1$, storage will be the same with the parastatal and a private sector monopoly. To investigate the relationship between optimal storage and the consumer bias, totally differentiate the first-order condition to get: $\frac{dS_t^*}{d\omega} = \frac{-\left(\alpha - E_t p_{t+1}^w\right)}{\gamma(2-3\omega)^2} < 0$. Thus, the greater the bias towards consumers, the lower is the level of storage. The intuition is that, by increasing consumption through having a positive consumer bias and thereby decreasing the consumer price, there is a reduced likelihood of making a profit from, or covering the costs of storage.

3.5 | Comparisons between private firm and parastatal intermediaries

We have now derived expressions for optimal consumption and storage under different market structures. The key variable that affects these structures is n for private firms and ω for the parastatal. This difference makes a direct comparison between the two market structures less than straightforward. Rather than choose a small set of specific values for these two key variables, we use instead a calibrated example to explore the relationships in greater detail. In the Appendix S1, we describe a dataset and calibrated parameters that were constructed using data

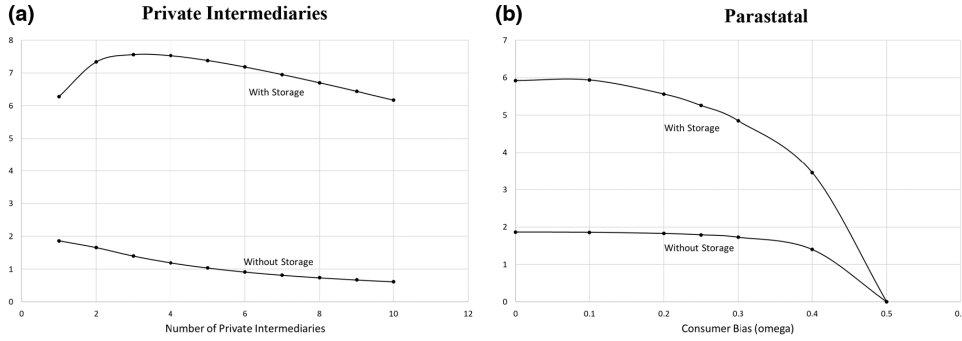

FIGURE 3 Profits with and without storage (m.EGP). (a) Private intermediaries (b) Parastatals.

from the Egyptian wheat market. Making use of the parameters which were calibrated to the *fino* (bakery products) data, we calculate values for consumption, consumer prices, storage and profits.

There is some critical value of the procurement price as a function of the number of intermediaries at which storage becomes zero. This value can be found from Equation (6) for the private firms by setting S_t to zero and solving for the procurement price, that is, critical $p_t^w = \beta\left(\alpha + nE_t p_{t+1}^w\right)/(n+1) - K$. For $n=1$, the critical world price is EGP 3036 and for $n=10$ it is EGP 2611. A lower procurement price of EGP 2500 was chosen. This price satisfies the critical value for storage to be positive. The higher value of the procurement price was set at EGP 3500, which makes storage unprofitable. For the parastatal (from Equation 6'), the critical value is EGP 3102 if $\omega=0$ and is EGP 2650 if $\omega=0.5$. Thus, the parastatal will procure for storage at the lower price but not at the higher.

Storage was calculated from Equations (6) and (6') using the lower of the two procurement prices; there is no storage at the higher price. The effects of market structure on storage are shown in Figure 2. For the private intermediaries, storage increases until $n=5$ and declines thereafter. This is consistent with the ambiguous sign of the change in storage with n shown earlier. For the parastatal, however, as the consumer bias increases, the level of stock holding decreases. This outcome is also consistent with the change in storage with respect to the consumer bias shown earlier. As n or as ω increases, the consumer price falls and with it the size of the mark-up, thereby making storage less profitable (see Equations 6 and 6').

Finally, we have noted that the incentive to store potentially offsets the negative consequences of higher import prices for profits. Profits with and without storage are shown as a function of the number of private intermediaries (Figure 3a) and as a function of the policy weight (Figure 3b). For each of the market structures, profits were calculated at each of the two values of the procurement price and then averaged. From Figure 3a, it can be concluded that profits initially increase until $n=3$, but then decline thereafter as the number of private intermediaries increases further. Average profits with storage exceed profits when there is no storage thus being consistent with the algebra given prior to Figure 1. From Figure 3b, storage makes a decreasing contribution to profits as the consumer bias increases.

4 | APPLYING THE THEORETICAL FRAMEWORK: THE EGYPTIAN WHEAT MARKET

We use the Egyptian wheat market as a case study to illustrate the insights from the theoretical model. In doing so, we extend the framework to take account of policy instruments that the Egyptian government employs and to consider the potential effects of reforms that have been

proposed recently in FAO (2015).[14] The application is not intended as a comprehensive assessment of the interaction between market structure and government policies in the Egyptian wheat market but only as an illustrative case-study highlighting the interaction between different types of intermediaries, government policies and storage.

The Egyptian wheat sector is characterised by both parastatal and private intermediaries, albeit functioning in different segments of the wheat supply chain. Rich detail is provided in a recent report (FAO, 2015) on the structure of this supply chain and on government policies in it. In particular, data are provided on storage costs for the parastatal and the private intermediaries. To analyse the effects of specific government policies, we require some amendments to the theoretical framework, which we detail below.

4.1 | Background

The Egyptian wheat sector comprises two segments: one which produces *baladi* bread and is focused on guaranteeing access to subsidised bread through government intermediaries; the other is the *fino* bread sector comprising private intermediaries which mill higher quality wheat for bakery products, including bread. Egypt also relies on imports from the world market.[15] The use of storage is an important feature of the supply chains with government agencies and private firms owning storage facilities in their respective segments. This segmented market allows us to consider policy issues where one segment is characterised by a state intermediary and the other by private firms. It also allows us to evaluate government policy options in the presence of intermediaries and storage, and to investigate alternative scenarios relating to changes in market structure.

Wheat is the most important grain crop in Egypt. It accounts for approximately 10% of the value of agricultural output and 20% of the value of imports (FAO, 2015).[16] The government employs various policy instruments to promote food security. These are targeted at both consumers of bread and producers of wheat. With more than one quarter of the Egyptian population below the poverty line, a food subsidy programme provides access to low-priced bread at a fixed maximum price. The final product, *baladi* bread (a form of flat bread), is available at 5 *piastres* per loaf (equivalent to 458 EGP/tonne of wheat[17]) which compares with a free market price of 36 *piastres* per loaf.[18] Reform of the *baladi* bread system remains a government priority because of its budgetary cost. Direct price intervention is also targeted at wheat producers for whom the government supports the procurement price. This price has been well in excess of import prices (on average by 32% between 2008 and 2017) adding considerably to the budgetary cost of government policies in the wheat sector.[19]

However, the role of government extends beyond these policy instruments. Through state agencies, the government is entirely responsible for the procurement of domestically produced wheat and is partially responsible for the procurement of wheat imports. These agencies include: the General Authority of Supply Commodities (GASC), which is responsible for around 40%

[14]An overview of food security issues focused on bread in Egypt can be found in Barnes (2022).

[15]In order to focus on how the structure of the intermediary market determines outcomes and the impact of changes in domestic market structure, we set aside any terms of trade effects vis-à-vis imports. In the cases we have here, any mark-down benefits from terms-of-trade effects dissipate as the intermediary sector becomes more competitive or the parastatal's pay-off function is more consumer-biased.

[16]Farmers are allowed to retain some wheat for household consumption. Consistent with the characterisation of the model, farmers are always net producers from which the state sector procures wheat.

[17]See the Appendix S1 for details of the calculation of this equivalence.

[18]The food subsidy programme has become increasingly expensive with 80% of the Egyptian population having ration cards that permit them access to subsidised bread.

[19]The costs associated with subsidised bread and high procurement prices (and fertiliser subsidies) amounts to 1% of Egyptian GDP (FAO, 2015).

of total wheat imports; the Principal Bank of Development and Agricultural Credit (PBDAC); and the Egyptian Holding Company for Silos and Storage (EHCSS). In what follows, we treat all these parastatals as a single entity. The state also controls almost all inland storage, most notably the flat storage system in jute bags known as *shona*. It is known that this form of storage is wasteful, and thus costly, because it is prone to inefficiencies in handling and to physical losses caused by pests, disease and weather (FAO, 2015). On the other hand, private firms use silos for storage.

Private sector involvement in the Egyptian wheat-bread supply chain relates mainly to the supply of *fino* bakery products. *Fino* products involve finer extraction of wheat to flour compared with the *baladi* system (72% for *fino* compared with 82% for *baladi* bread). Private firms import from world markets and are involved in storage, milling and distribution of *fino* products where greater efficiency and a higher selling price are reflected in higher margins. The *fino* and *baladi* supply chains are segmented, reflecting differences in procurement channels, the different quality of *baladi* and *fino* bread and the use of ration cards for *baladi* bread exchangeable at *baladi* outlets. This segmented market structure is the basis for an application of the framework of Section 3. We consider two reforms. The first relates to subsidised *baladi* bread and the second to a change to market structure. Our principal focus is on how the interaction of intermediaries and the existence of storage help to determine the costs of government policies and the provision of food security.

4.2 | Amendments to the theoretical framework

To accommodate price policy instruments, we amend the basic theoretical model of Section 3. In all other respects, the basic framework remains the same with regard to domestic production, to exogenous world prices, and to the pay-off functions for private intermediaries and the parastatal.

As noted above, the wheat value chain is segmented between *baladi* bread and *fino* products. We highlight this distinction by superscripts b and F respectively. In addition, the storage costs of the parastatal and the private intermediaries are different because of the different types of storage facility that each employs. In place of K (see Section 3), we let K^b be the one-period storage cost of one tonne of wheat for the parastatal and K^F for the private intermediaries, with $K^b < K^F$. The difference in the type of storage facility is also reflected in storage losses as a proportion of stock carry-out. In Section 3 we ignored these losses altogether but here we account for them in λ^b and λ^F with $\lambda^b > \lambda^F$. The third amendment is the incorporation of the inefficiency of the parastatal in procuring imports and we do this by introducing ι as the additional cost per tonne imported.

4.3 | Current instruments: Fixed consumer and producer prices

Current policy instruments in the wheat sector involve a fixed and (implicitly) subsidised *baladi* bread price for poorer consumers and a fixed procurement price in excess of world market prices for domestic wheat producers. The parastatal is the sole procurer from domestic wheat producers. Procurement in excess of domestic production for distribution and storage is from imports. Private intermediaries are involved only in the *fino* segment and they source wheat for distribution and storage solely from imports. The data for the Egyptian wheat market given in the Appendix S1 reflect these instruments and market structure, and they provide the base from which we measure the effects of changes in the policy instruments and market structure.

4.4 | Alternative instruments: Fixed consumer and producer per unit subsidies

In the case of fixed consumer and producer prices, the costs of the (implicit) consumer subsidies are determined by world prices and the corresponding level of consumption. In the case of producer subsidies, the costs are determined by world prices and by realised domestic production. Therefore,

the government has little control over the budgetary costs. As an alternative means of limiting these costs, the level of explicit unit subsidies could be fixed. These instruments are still targeted towards the objectives of food security and livelihood security, although not fixing prices introduces a degree of variance in prices for consumers and unit returns to producers. By assuming that consumers and producers are risk neutral, the induced variability in prices will not be of concern, although changes in the mean level of prices will be. This change of instruments affects the level of imports needed to meet variable consumption levels and storage.[20] The consumer and producer unit subsidies enter into the parastatal's pay-off function. Since these instruments apply only in the *baladi* segment, the characterisation of the intermediaries in the *fino* segment remains unchanged.

Inclusive of the per unit consumer and producer subsidies, the parastatal's profit from sales to consumers is now given by:

$$\pi_t^b = \left[p_t^b + s_c - p_t^w - s_p\right] h_t + \left[p_t^b + s_c - p_t^w - \iota\right] m_t^b + \left[p_t^b + s_c\right]\left(1-\lambda^b\right) S_{t-1}^b \tag{7}$$

where s_c is the unit consumer subsidy and s_p the unit production subsidy. The parastatal's complete objective function remains that given in Equation (2'). Substituting Equation (7) into Equation (2') and differentiating gives the optimal level of consumption:

$$C_t^{b*} = \frac{(1-\omega)\left(\alpha^b + s_c - p_t^w - \iota\right)}{\gamma^b(2-3\omega)} \tag{8}$$

the corresponding consumer price being given by:

$$p_t^{b*} = \frac{\alpha^b(1-2\omega) + (1-\omega)\left(-s_c + p_t^w + \iota\right)}{(2-3\omega)} \tag{9}$$

Using Equations (2') and (9), the corresponding decision to store is given by:

$$S_t^{b*} = \begin{cases} \dfrac{1}{\gamma^b\left(1-\lambda^b\right)}\left[\dfrac{(1-2\omega)\left(\alpha^b + s_c\right) + (1-\omega)E_t p_{t+1}^w}{(2-3\omega)} - \dfrac{\left(p_t^w + K + \iota\right)}{\beta}\right], S_t^{b*} > 0 \\ 0, \text{otherwise} \end{cases} \tag{10}$$

The per unit subsidy provides an incentive to store through increasing the realised unit return and it offsets the negative bias towards storage in the pay-off function given by ω (see Figure 3b). Note that the per unit producer subsidy does not affect the storage decision. However, it does affect the parastatal's profits and the budgetary costs of the programme. We therefore include it in the assessment that follows in Section 5.

In the *fino* segment, there are n private intermediaries. Procurement for consumption and storage in this segment comes from imports only as given by $C_t^F = m_t^F + \left(1-\lambda^F\right) S_{t-1}^F$. The inverse demand function for *fino* bread is given by:

$$p_t^F = \alpha^F - \gamma^F\left(m_t^F + \left(1-\lambda^F\right) S_{t-1}^F\right) \tag{11}$$

The expressions for aggregate consumption, price and aggregate storage corresponding to (3), (4) and (6) are given by:

$$C_t^{F*} = \frac{n\left(\alpha^F - p_t^w\right)}{\gamma^F(n+1)} \tag{12}$$

[20]The variability of import needs raises the matter of availability of foreign exchange. In the simulations undertaken, a foreign exchange constraint was imposed but it was found never to be binding.

$$p_t^{F*} = \frac{\alpha^F + np_t^w}{(n+1)} \tag{13}$$

$$S_t^{F*} = \begin{cases} \dfrac{n}{\gamma^F\left(1-\lambda^F\right)}\left[\dfrac{\left[\alpha^F + nE_t p_{t+1}^w\right]}{(n+1)} - \dfrac{\left[p_t^w + K\right]}{\beta}\right], S_t^{F*} > 0 \\ 0, \text{otherwise} \end{cases} \tag{14}$$

4.5 | Private intermediaries in the parastatal sector

In the FAO review of the Egyptian wheat sector (FAO, 2015), there was a proposal to allow private intermediaries engaged in the *fino* segment to supply wheat to the parastatal in the *baladi* segment. Specifically, the parastatal would continue to absorb all domestic production but wheat in excess of this quantity that is required for consumption (denoted by G_t) would come from the private intermediaries rather than from imports.[21] This change would reduce the cost of imports by ι per tonne. In contrast to the previous case, the parastatal does not hold stocks either, thereby decreasing overall losses in storage. We assume that the private intermediaries would only have the incentive to supply the parastatal if they received the same price as they would obtain by selling to consumers of *fino* products. We also assume that the per unit consumer and producer subsidies still apply.

The inverse demand function facing the parastatal in the *baladi* segment is now given by:

$$p_t^b = \alpha^b - \gamma^b(h_t + G_t) = \alpha^b - \gamma^b C_t^b \tag{15}$$

with profits from sales, inclusive of the cost of procurement from private intermediaries, given by:

$$\pi_t^b = \left[p_t^b + s_c - p_t^w - s_p\right]h_t + \left[p_t^b + s_c - p_t^F\right]G_t \tag{16}$$

Substitution of Equation (16) into Equation (2'), making use of Equation (20) (see below), and differentiating the result with respect to G_t, gives:

$$(1-\omega)\left(\alpha^b + s_c\right) - \gamma^b(2-3\omega)h_t - \left[\gamma^b(2-3\omega) + \frac{(1-\omega)\gamma^F}{n+1}\right]G_t - (1-\omega)p_t^F = 0 \tag{17}$$

Letting $\gamma^b(2-3\omega)h_t \equiv \theta_{2,t}$ and $\left[\gamma^b(2-3\omega) + \frac{(1-\omega)\gamma^F}{n+1}\right] \equiv \theta_1$, Equation (17) can be rewritten as: $\theta_1 G_t + (1-\omega)p_t^F = (1-\omega)\left(\alpha^b + s_c\right) - \theta_{2,t}$.

The *fino* market remains segmented so the inverse demand function remains as in (11) but profits for intermediaries will now also include sales to the parastatal. The profit function for a representative private intermediary is given by:

$$\pi_t^{Fi} = \left(p_t^F - p_t^w\right)m_t^{Fi} + \left(p_t^F - p_t^w\right)g_t^i + p_t^F\left(1-\lambda^F\right)s_{t-1}^{Fi} + \left(\beta E_t p_{t+1} - p_t^w - K\right)s_t^{Fi} \tag{18}$$

where g_t^i are sales by the ith intermediary to the parastatal. Maximising Equation (18) with respect to c_t^{Fi} and aggregating over the number of private intermediaries gives aggregate consumption and the associated price as:

[21]Other permutations of the private sector competing with a parastatal in distribution and/or procurement can be found in McCorriston and MacLaren (2016). Importantly, however, they ignore the role of storage in these markets, which is an obvious channel for addressing food security in volatile markets.

$$C_t^{F*} = \frac{n\left(\alpha^F - \gamma^F n g_t^i - p_t^w\right)}{\gamma^F (n+1)} \tag{19}$$

$$p_t^{F*} = \frac{\alpha^F + \gamma^F n g_t^i + n p_t^w}{(n+1)} \tag{20}$$

Equations (17) and (20) include the two unknowns, G_t and p_t^F. Rewrite Equation (20) as $(n+1)p_t^F - \gamma^F G_t = \alpha^F + np_t^w$. Then in matrix form the two equations are:

$$\begin{pmatrix} \theta_1 & (1-\omega) \\ -\gamma^F & (n+1) \end{pmatrix} \begin{pmatrix} G_t \\ p_t^F \end{pmatrix} = \begin{pmatrix} (1-\omega)\left(\alpha^b + s_c\right) - \theta_{2,t} \\ \alpha^F + np_t^w \end{pmatrix} \tag{21}$$

with the solution:

$$\begin{pmatrix} G_t \\ p_t^F \end{pmatrix} = \frac{1}{\gamma^F(1-\omega) + \theta_1(n+1)} \begin{pmatrix} (n+1)\left[(1-\omega)\left(\alpha^b + s_c\right) - \theta_{2,t}\right] - (1-\omega)\left(\alpha^F + np_t^w\right) \\ \gamma^F\left[(1-\omega)\left(\alpha^b + s_c\right) - \theta_{2,t}\right] + \theta_1\left(\alpha^F + np_t^w\right) \end{pmatrix} \tag{22}$$

The key insight from this changing role of private intermediaries is that, even though the consumers of *baladi* bread and *fino* products are segmented, the *fino* price depends nevertheless on the bias in the parastatal's pay-off function, and sales in the *baladi* segment depend on the *fino* price. In addition, with the private intermediaries solely responsible for storage, their storage decision is also influenced by the weight in the parastatal's pay-off function.

To see this, consider the intermediaries' storage decision which is given by Equation (14). It can be rearranged and re-expressed for the ith intermediary to get:

$$s_t^{Fi*} = \begin{cases} \dfrac{\beta E_t p_{t+1} - p_t^w - K^F}{\gamma^F\left(1-\lambda^F\right)}, s_t^{Fi*} > 0 \\ 0, \text{otherwise} \end{cases}$$

Take the second equation in (22), advance time by one period and take expectations with respect to time t to obtain:

$$E_t p_{t+1}^F = D^{-1}\left\{\gamma^F\left[(1-\omega)\left(\alpha^b + s_c\right) - E_t\theta_{2,t+1}\right] + \theta_1\left(\alpha^F + nE_t p_{t+1}^w\right)\right\} \tag{23}$$

where $D = \theta_1(n+1) + \gamma^F(1-\omega)$, and θ_1 and $\theta_{2,t}$ are given as above. Define $E_t\theta_{3,t+1} \equiv \left\{\gamma^F\left[(1-\omega)\left(\alpha^b + s_c\right) - E_t\theta_{2,t+1}\right] + \theta_1\left(\alpha^F + nE_t p_{t+1}^w\right)\right\}$. Then the storage decision for a private intermediary is given by:

$$s_t^{Fi*} = \begin{cases} \dfrac{1}{\gamma^F\left(1-\lambda^F\right)}\left[\beta D^{-1} E_t\theta_{3,t+1} - p_t^w - K^F\right] \\ 0, \text{otherwise} \end{cases}, s_t^{Fi*} > 0 \quad (24)$$

with aggregate stocks given by $S_t^{F*} = ns_t^{Fi*}$. Given the definitions of θ_1, $\theta_{2,t}$ and $\theta_{3,t+1}$, the higher weight the parastatal places on consumer welfare and the higher per unit subsidies on *baladi* bread, the greater the level of storage. This conclusion is substantiated by the results given in Table 2. We now have a basis for providing an assessment of these proposed policy reforms in the presence of intermediaries.

5 | DATA, CALIBRATION AND RESULTS

5.1 | Data and calibration

The FAO report provides details about the levels of procurement by the parastatal and private firms from domestic farmers and imports, on storage capacity in each sector including data on costs, and information on the level of *baladi* subsidies and domestic procurement prices. We complement these data with data on domestic production, consumption, world and domestic prices from AMIS (2020). Details on the demand and supply elasticities used in the calibration of the parameters and the treatment of the stochastic variables are provided in the Appendix S1.

5.2 | Results: Changes in policy instruments

We report in Table 1 the outcomes of one potential reform to the current policy of fixed consumer and producer prices. We replace these instruments with per unit consumer and producer subsidies. The benchmark pre-reform simulated values are reported in the first column.[22] In terms of gauging the impact of the change to a per unit consumer subsidy, as noted in Section 4, the outcome will depend on the consumer bias in the parastatal's pay-off function. We therefore report three alternatives: one where the parastatal is equivalent to a profit maximising monopoly (i.e., $\omega = 0$) and two cases where there are different levels of bias towards consumers (i.e.,$\omega = 0.25$ and $\omega = 0.5$).[23]

Reading across the three columns relating to the policy weight, the values show clearly the significance of the parastatal's pay-off function in determining the outcomes of the consumer subsidy. In terms of the level of consumption and consumer prices, the results are in line with expectations (see Section 3): the greater the consumer bias, the higher the levels of consumption and the lower the consumer price. Similarly, the consequence is that the incentive to store decreases as is evident by the changes in the levels of storage. As the consumer bias increases from $\omega = 0$ to $\omega = 0.5$, the level of stocks decreases to only 11% of its former level.

The parastatal's profits, although higher than in the fixed-price consumer policy, decrease as the consumer bias rises. With $\omega = 0$, profits from storage account for around 58% of the parastatal's profits; when $\omega = 0.25$, storage profits account for 48%. Note that the share in overall profits is largely determined by the combination of the decline in the consumer price as the

[22]Note that we do not consider changes to the fixed price for *baladi* bread because the storage rule cannot determine the level of stocks with fixed consumer prices.

[23]As far as we are aware, there is no precise measure of the value of the weights in the parastatal's pay-off function so we explore several alternatives. Despite the absence of a precise number, values of $\omega > 0$ are consistent with the food security objectives of the Egyptian government and the use of the *baladi* bread subsidy.

TABLE 1 Outcomes from the use of alternative policy reforms in the *baladi* segment (mean values).

			Fixed per unit consumer and producer subsidies			
			Producer subsidy: EGP 655.5/tonne			
			Consumer subsidy			
			EGP 2440/tonne		EGP 1500/tonne	
Variable	Actual data	Simulated pre-reform levels	$\omega = 0$	$\omega = 0.25$	$\omega = 0.5$	$\omega = 0.25$
Consumption (mmt)	7.50	7.50	5.61	6.75	11.24	4.16
Production (mmt)	2.85	3.11	3.06	3.06	3.06	3.06
Imports (mmt)	4.95	4.52	5.71	5.44	8.30	3.25
Stocks (mmt)	2.36	2.36[a]	4.99	3.81	0.56	2.32
Consumer price (EGP/tonne)	458	458	870	622	107	1186
Procurement price (EGP/tonne)	2800	2800	2587	2580	2583	2582
Parastatal's profits (m.EGP)	n.a.[b]	−2095	7783	6272	4998	2297
Profits from storage (m.EGP)	n.a.	-	4543	2994	411	1396
Budgetary cost of consumer subsidy (m.EGP)	18,309	12,189	13,701	16,476	27,431	6243
Budgetary cost of producer subsidy (m.EGP)	1869	2327	2004	2004	2004	2005

[a]As noted above, with fixed consumer prices, the storage rule does not apply. The pre-reform level of stocks is therefore taken from the share of storage capacity accounted for by the parastatal which is estimated at 53.76% (FAO, 2015). On average, total storage capacity over the 2008/09 and 2017/18 period is 4.38 mmt which gives parastatal stocks as (0.5376 × 4.388) 2.355 mmt.

[b]Data not available.

TABLE 2 Impacts of changing procurement patterns (mean values).

***Baladi* sector**

		$n = 5$			$n = 20$		
Variables	Simulated pre-reform	$\omega = 0$	$\omega = 0.25$	$\omega = 0.5$	$\omega = 0$	$\omega = 0.25$	$\omega = 0.5$
Consumption (mmt)	7.5	5.00	5.86	8.98	5.68	6.76	11.00
Procurement from private firms (mmt)	-	1.90	2.76	5.88	2.57	3.66	7.85
Consumer price (EGP/tonne)	458	1003	815	235	856	619	101
Parastatal's profits (m.EGP)	−2095	5094	4881	2145	5812	5506	4372
Budgetary cost of consumer subsidy (m.EGP)	12,187	12,217	14,312	21,924	13,858	16,506	26,737
Budgetary cost of domestic procurement (m. EGP)	2327	2036	2036	2036	2036	2036	2036

***Fino* sector**

		$n = 5$				$n = 20$		
Variables	Simulated pre-reform	$\omega = 0$	$\omega = 0.25$	$\omega = 0.5$	Simulated pre-reform	$\omega = 0$	$\omega = 0.25$	$\omega = 0.5$
Consumption	9.727	9.41	9.26	8.74	11.10	10.99	10.94	10.72
Imports	9.720	11.39	12.17	14.78	11.12	13.64	14.66	18.69
Stocks	1.465	2.94	3.00	3.26	1.11	2.37	2.28	2.49
Consumer	2249	2301	2327	2412	2020	2039	2048	2083
Private	4032	6520	7023	9196	1705	4230	4428	5244
Private firms' profits	-	2263	2359	2697	1904	1456	1488	1584

pro-consumer bias increases and size of the fixed per unit consumer subsidy. In terms of other changes arising from the change in the policy instruments, imports increase by around 44% over the range of values of the policy weight. Importantly, the cost of the consumer subsidy policy increases significantly with increases in the pro-consumer bias because of the increase in consumption.

However, the level of storage will also depend on the level of the consumer subsidy (see Equation 24). If the government were concerned about the budgetary cost of the consumer subsidy programme, it could choose to reduce the unit subsidy while having to accept the consequent reduction in food security as measured by consumption. The effect of reducing the unit subsidy from its value in the data (EGP 2440) to EGP 1500 is shown in the final column in Table 1. As would be expected, a reduction in the unit subsidy, at the same value of the policy weight (0.25), will increase the consumer price and decrease consumption. Despite this increase in price, stock carry-out decreases and with it the parastatal's profits, while profits from storage now accounts for around 45% of parastatal's profits. The most significant effect of the reduced unit subsidy is on the budgetary cost of the consumer subsidy policy, which falls to two-fifths of its previous level. Thus, a decrease of two-fifths in consumption is associated with the budgetary savings of three-fifths.

The overall headline to take away from Table 1 is not per se the accuracy of specific metrics but rather that the interaction of instrument choice and the parastatal's pay-off function generate substantial differences in outcomes for the variables shown. There are two reinforcing effects. First, as the bias in the parastatal's pay-off function tends towards consumers, the incentive to store declines. Second, lower (higher) levels of the per unit consumer subsidy discourage (encourage) storage. Taken together, the scenarios presented above highlight the role that profits from storage can play in determining the overall outcomes from policy reforms that interact with the characterisation of the objectives of the parastatal.

5.3 | Results: Changes in market structure

As noted above, the case we explore here is one in which the parastatal continues to purchase all domestic production, but it no longer holds stocks nor imports, and instead procures wheat from private domestic intermediaries which source exclusively from world markets to make up the difference between optimal consumption and realised domestic production.

The effects on a range of metrics are reported in Table 2. The evaluation of these effects depends jointly on how competitive the *fino* sector is and the bias in the parastatal's pay-off function. We consider three permutations for each characterisation of the private firms and the parastatal. These allow for alternative characterisations of the extent of competition in the private intermediary sector and the pro-consumer bias in the parastatal's pay-off function.[24] In addition to the changes brought about by these characterisations, there is also the impact on storage that is brought about by the private firms being relatively more efficient than the parastatal (in the sense of having smaller storage losses), which consequently increases profits from storage. In terms of explicit policy instruments targeted at food security, we assume the fixed per unit subsidies are at the initial values in Table 1. As the results in Table 2 show, reforming market structure generates a wider range of effects compared with the previous reform scenarios reported in Table 1.

[24]Although FAO (2015) provides considerable detail concerning the *baladi* and *fino* supply chains, it does not provide information on the number of private intermediaries. However, different perceptions about the intensity of competition can be addressed in our framework by choosing a relatively concentrated private firm benchmark ($n = 5$) and a more competitive one ($n = 20$). Although free entry into the *fino* sector could be assumed, it is unlikely to be more informative than assuming alternative characterisations of private sector competition as this is an issue where proposed marketing reforms have raised concerns from interest groups.

Consider, first of all, the case where $n = 5$. As the consumer bias increases, consumption rises and the consumer price falls. With the parastatal no longer storing nor importing, the private firms correspondingly increase the levels of storage and imports because they are supplying the *baladi* bread segment as well as consumers of *fino* bread. This change in the procurement pattern results in positive but decreasing profits for the parastatal because it is having to pay higher *fino* consumer prices for part of its procurement as it purchases more. In addition, it no longer experiences storage losses nor is it procuring imports at a price that includes the costs of its inefficiency (ι). Unless the parastatal is equivalent to a private monopoly, which results in higher prices for *baladi* bread, the change in the procurement pattern increases the budgetary cost of providing consumer subsidies by around 17% (when $\omega = 0.25$) and 80% (when $\omega = 0.5$), due to the *fino* prices that the parastatal has to pay for procurement to the private firms. It can be concluded that a combination of a change in policy instruments together with the change in market structure does not achieve the objective of reducing expenditure on the consumer subsidy. However, this combination does reduce the fiscal cost of the consumer subsidy when compared with the change in policy instrument alone (compare the corresponding entries in Tables 1 and 2).

Profits for the private intermediaries are higher than in the benchmark and they are increasing as the consumer bias increases, largely due to the increasing levels of consumption in the *baladi* bread sector and the assumption that the private firms are paid their consumer price by the parastatal. However, and consistent with the theoretical framework, these outcomes turn out to be sensitive to the characterisation of the parastatal's pay-off function and the extent of competition in the *fino* sector. In comparing the results for $n = 5$ with those of $n = 20$ across the values of the consumer bias, it is noticeable that the effects of the policy weights are dampened in the more competitive case. This dampening affects each of the variables but especially the private firms' profits.

Note specifically the effects on storage in this reform scenario: as the bias in the parastatal's pay-off function rises, the level of storage increases even though consumption in the *fino* sector decreases. This is contrary to the outcomes reported in Table 1 where storage fell as the consumer bias rose. Profits from storage as a share of total profits vary with the parastatal's pay-off function. In the scenario with $n = 5$, with $\omega = 0$, storage profits account for 35% of private firms' profits (not shown); with $\omega = 0.5$, this share declines to around 30%. Overall, the effects on storage in policy reforms therefore depend on a number of factors, including market structure.

5.4 | Summary

The central takeaway from this section is that the theoretical framework set out in Sections 3 and 4 can be used to analyse the consequences of policy reforms in a stochastic, open economy, small-country environment where the role of storage is accommodated. In the context of the policy reforms, we have shown that the pay-off function of the parastatal and the extent of competition in the private sector matter in determining the outcomes across a range of metrics. We have also shown that the interaction of these types of market intermediaries is important in evaluating alternative policy instruments. In short, this illustrative case-study highlights that the characterisation of the intermediary market plays a crucial role in the effectiveness of reforms. Clearly, we can employ different permutations of the policy instruments used, the pro-consumer bias of the parastatal and intensity of competition between private sector firms, but the scenarios presented above highlight the insights from the theoretical framework and give some guide to their relative importance. Notably, the effect on storage of this policy reform depends on the bias in the parastatal's pay-off function, the extent of competition in the private sector and on the specifics of the interaction between the parastatal and the

private sector. In terms of the overall assessment of policy reforms, this illustration shows that accounting for the role of profits from storage contributes an important insight into the distribution of welfare changes.

6 | CONCLUSION

Intermediaries play a crucial role in the functioning of agricultural and food markets and can be important in determining the effectiveness of government policies designed to promote food security. In the form of parastatals, they are also an important instrument in the delivery of government policy objectives, including that of food security. Aside from procurement and distribution, they are also involved in commodity storage. We have compared parastatals with private sector intermediaries where parastatals are differentiated from private firm intermediaries by the nature of their pay-off function. These features add complexity to determining whether parastatals store more or less than private firm intermediaries and, therefore, which form provides relatively greater or lesser food security. We have applied the framework to an illustrative case study of the Egyptian bread-wheat market where food security is an over-riding government concern and we have analysed how price instruments interact with market structure and commodity storage to determine outcomes. The main insight that comes out of these policy simulations is that in markets where storage is important in ameliorating volatility, the nature and functions of intermediaries also have a significant impact on the costs and effectiveness of those government policies that are aimed at promoting food security. In addition, the levels and profits from storage have an important influence on the distributional effects of these policy reforms. The headline contribution of the analysis is that, in line with recent research on market structure more generally, accounting for intermediaries in markets where commodity storage has a role is important in determining the costs and benefits of agricultural policies and the delivery of food security outcomes.

There remain several avenues for future research. We have assumed risk-neutral market intermediaries, risk-neutral consumers and a risk-neutral government. These assumptions have served the purpose of providing a framework in which we can readily generate some insights about the importance of market structure and especially how the outcomes from policy choices may depend on the characterisation of that structure. Extending the framework to incorporate aspects of risk aversion on the part of market intermediaries, consumers and government would be important to explore. Private intermediaries may be concerned about the variance of profits because these can affect the intensity of competition (Asplund, 2002). Aside from the more obvious aspect of consumer risk aversion, if a government is also concerned about consumer risk, this would be reflected in the specification of the parastatal's pay-off function, which would also include a term for the variance of consumer surplus. Another extension worth exploring would be to change the parastatal's pay-off function to have it based instead on loss aversion or on safety-first criteria. Recent research has investigated the issue of loss aversion in trade policy (Tovar, 2009) and with applications to trade policy in food markets (Giordani et al., 2016). Loss aversion is premised as being part of the government's objectives but, in a context characterised by market volatility, addressing loss aversion in the pay-off functions of the parastatal will be an interesting amendment to how the role of the state in providing food security is evaluated.

Finally, the recent storage/trade literature has focused on the issue of optimal trade and storage policies (see, e.g., Gouel, 2016; Gouel & Jean, 2015). Yet, the derivation of optimal policies ignores the key aspects of market structure where food security issues are pertinent. Extending the analysis of optimal policies to account for market structure will also be an important avenue for future research.

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REFERENCES

Alderman, H., Gentilini, U. & Yemstov, R. (2018) *The 1.5 billion people question: food, vouchers or cash transfers*. Washington: World Bank.

Allaz, B. (1991) Duopoly, inventories and futures markets. In: Phlips, L. (Ed.) *Commodity, futures and financial markets. Advanced Studies in Theoretical and Applied Econometrics*, Vol. 21. Dordrecht: Kluwer Academic, pp. 279–271.

AMIS. (2020) Market Database. Available from: http://www.amis-outlook.org/home/en/ [Accessed 16 March 2023]

Asplund, M. (2002) Risk averse firms in oligopoly. *International Journal of Industrial Organisation*, 20, 995–1012.

Atkin, D. & Donaldson, D. (2015) Who's getting globalized? The size and implications of intra-national trade costs. NBER Working Paper No. 21439.

Avram, L. (1984) Some examples of dynamic Cournot duopoly with inventory. *RAND Journal of Economics*, 16, 569–578.

Barnes, J. (2022) *Staple security: bread and wheat in Egypt*. Durham: Duke University Press.

Barrett, C.B. & Mutambatsere, E. (2008) Agricultural markets in developing countries. In: Blume, L.E. & Durluaf, S.N. (Eds.) *The new Palgrave dictionary of economics*, 2nd edition. London: Palgrave Macmillan.

Barrett, C.B.T., Reardon, J.S. & Zilberman, D. (2020) Agri-food value chain revolution in low and middle income countries. *Journal of Economic Literature*, 60, 1316–1377.

Bergazo, T. & Nymen, S. (2016) *Competition and poverty: how competition affects the distribution of welfare*. Washington: World Bank.

Bieri, J. & Schmitz, A. (1974) Market intermediaries and price instability: some welfare implications. *American Journal of Agricultural Economics*, 56, 280–285.

Cadot, O., Dutoit, L. & De Melo, J. (2009) The elimination of Madagascar's vanilla marketing board, 10 years on. *Journal of African Economies*, 18(3), 388–430.

Choi, J.P. & Thum, M. (2009) The economics of politically-connected firms. *International Tax and Public Finance*, 16, 605–620.

Dhingra, S. & Tenreyro, S. (2020) The rise of agribusiness and the distributional consequences of policies on intermediated trade. Unpublished working paper, LSE.

Faccio, M. (2006) Politically-connected firms. *American Economic Review*, 96, 369–386.

FAO. (2015) *Egypt: wheat sector review*. Rome: FAO Investment Centre, Food and Agriculture Organisation.

Fulton, M.E. & Reynolds, T. (2015) The political economy of food price volatility: the case of Vietnam and Rice. *American Journal of Agricultural Economics*, 97, 1206–1226.

Ganesh-Kumar, A., Devish, R. & Gulati, A. (2010) *Liberalizing foodgrains markets: experiences, impact and lessons from South Asia*. New Delhi: Oxford University Press.

Giordani, P.E., Rocha, N. & Ruta, M. (2016) Food prices and the multiplier effect of trade policy. *Journal of International Economics*, 101, 102–122.

Gouel, C. (2016) Trade policy coordination and food price volatility. *American Journal of Agricultural Economics*, 98, 1018–1037.

Gouel, C. & Jean, S. (2015) Optimal food price stabilization in small open developing countries. *World Bank Economic Review*, 29, 71–101.

Jayne, T.S., Zulu, B. & Nijhoff, J.J. (2006) Stabilising food markets in eastern and southern Africa. *Food Policy*, 31, 328–341.

Larson, D.F., Lampietti, J., Gouel, C., Cafiero, C. & Roberts, J. (2014) Food security and storage in the Middle East and North Africa. *World Bank Economic Review*, 28, 48–73.

Macchiavello, R. & Marjaria, A. (2019) *Competition and relational contracts in the Rwanda coffee chain*' CEPR discussion paper 13607. London: Centre for Economic Policy Research.

McCorriston, S. (2015) Competition and food security. In: *Background note for FAO state of agricultural commodity markets, 2015*. Rome: Food and Agriculture Organisation.

McCorriston, S. & MacLaren, D. (2007) De-regulation as (welfare reducing) trade reform. *American Journal of Agricultural Economics*, 89, 637–650.

McCorriston, S. & MacLaren, D. (2016) Food security, welfare and partial deregulation of parastatals. *Oxford Economic Papers*, 68(3), 836–856.

McLaren, J. (1999) Speculation in primary commodities: the effects of restricted entry. *Review of Economic Studies*, 66, 853–871.

Narayan, S. (2020) The three farm bills. *India Forum*. Available from: The Three Farm Bills | The India Forum. [Accessed 20th October 2021].

Newbery, D.M.G. (1984) Commodity price stabilization in imperfect or cartelized markets. *Econometrica*, 52, 363–378.

Porto, G., Chauvin, N.D. & Olarreaga, M. (2011) *Supply chains in export agriculture, competition, and poverty in sub-Saharan Africa*. Washington: World Bank.

Rashid, S., Gulati, A., Cumming, R. & Jnr, R. (Eds.). (2008) *From parastatals to private trade*. New York: John Hopkins University Press.
Reardon, T. (2015) The hidden middle: the quiet revolution in the midstream of agri-food value chains in developing countries. *Oxford Review of Economic Policy*, 31(1), 45–63.
Rotemberg, J.T. & Saloner, G. (1989) The cyclical behaviour of strategic inventories. *Quarterly Journal of Economics*, 104, 73–97.
Sexton, R., Sheldon, I.M., McCorriston, S. & Wang, H. (2007) Agricultural trade liberalisation and economic development: the role of downstream market power. *Agricultural Economics*, 36, 253–270.
Swinnen, J.F., Deconinck, K., Vandemoortele, T. & Vandenplas, A. (2015) *Quality standards, value chains and international development*. Cambridge: Cambridge University Press.
Thille, H. (2006) Inventories, market structure and price volatility. *Journal of Economic Dynamics and Control*, 30, 1081–1104.
Tovar, P. (2009) The effects of loss aversion on trade policy: theory and evidence. *Journal of International Economics*, 78, 154–167.
Williams, J.C. & Wright, B.D. (1991) *Storage and commodity markets*. Cambridge: Cambridge University Press.
World Bank. (2016) *Breaking down barriers: unlocking Africa' potential through vigorous competition policy*. Washington: World Bank.

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