FAO COMMODITY AND TRADE POLICY RESEARCH WORKING PAPER

No. 29

THE USE OF ORGANIZED COMMODITY MARKETS TO MANAGE FOOD IMPORT PRICE INSTABILITY AND RISK

Alexander Sarris , Piero Conforti and Adam Prakash

November 2009

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THE USE OF ORGANIZED COMMODITY MARKETS TO MANAGE FOOD IMPORT PRICE INSTABILITY AND RISK [1]

Abstract

The paper explores the possibility of insuring the price risks of wheat and maize imports of low income food deficit countries (LIFDCs). Optimal strategies when the importing agent can hedge with futures and options are derived under the assumption that the objective of food import agents is to minimize the unpredictability of import bills. A set of LIFDCs that account for a large share of the LIFDC wheat and maize imports is considered for ex-post simulations. It is shown that the world reference market for the wheat and maize imports of the LIFDCs are significantly related to the futures market of the Chicago Board of Trade (CBOT), thus opening the possibility of CBOT being a hedging market for LIFDC wheat and maize imports. Simulations of the optimal hedging rules are conducted for the period 1986-2008 with actual CBOT futures and options data, to explore the extent to which they could have reduced unpredictability in import bills, both during a normal period and a period of global price spikes like the one that occurred during 2007-8. It is shown that hedging with futures alone offers considerable opportunities for reducing food import unpredictability, and the same holds with options hedging, albeit to a lesser extent. The reductions in unpredictability could have been much higher during the recent crisis period. It is shown that hedging with either futures or options could have also reduced the average cost of basic food imports during the recent price spike.

JEL Subject Codes. Q18,Q13, Q17

Keywords. Food import bill unpredictability and instability, commodity price insurance, hedging developing country food import bills.

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[1] A. Sarris (corresponding author) is Director, P. Conforti and A. Prakash are economists, all in the Trade and Markets Division of FAO. Address: Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, Rome, 00153 Italy. E-mail addresses: alexander.sarris@fao.org, piero.conforti@fao.org, adam.prakash@fao.org. Fax + (39) 06 5705-4495.

The authors would like to acknowledge very helpful comments by Christopher Gilbert, by participants at a World Bank conference on managing food price risk and instability in low income countries in Washington DC held in February 2005, by participants at the International Task Force on Commodity Risk Management conference in Pretoria, South Africa in May 2006, and by participants at an expert workshop on managing global market risks held in Rome in October 2009. Several insightful comments by referees are gratefully acknowledged.

1. INTRODUCTION

The sudden and unpredictable increases in many internationally traded food commodity prices in late 2007 and early 2008 caught all market participants, as well as governments by surprise and led to many short term policy reactions that may have exacerbated the negative impacts of the price rises. The recent food commodity market spike occurred in the midst of another important longer term development in world agricultural trade. Over the last decade there has been a shift of developing countries from a position of net exporters - up to the early 1990's - to that of net agricultural importers (Bruinsma, 2003). Projections to 2030 indicate a deepening of this trend (ibid.), which is due to the projected decline in the exports of traditional agricultural products, such as tropical beverages and bananas, combined with a projected large and growing deficit of basic foods, such as cereals, meat, dairy products, and oil crops. Within developing countries, those classified as Least Developed Countries (LDCs) have witnessed a fast worsening of their agricultural trade balance in the last fifteen years. Since 1990, the food import bills of LDCs have not only increased in size, but also in importance, as they constituted more than 50 percent of their total merchandise exports in all years. In contrast, the food import bills of other developing countries (ODCs) have been stable or declined as shares of their merchandise exports (FAO 2004). The global food crisis of 2007-2008 brought this problem to the fore, as the basic food import bills of these countries increased considerably. Between 2007 and 2008, the food import bills of LIFDCs increased by 37.5 percent from US$88 billion to US$121 billion, before declining to an estimated US$93 billion in 2009 (FAO 2009a).

A study by GÜRKAN, ET.AL. (2003) indicated that between the mid-1980s and 1990s, the LDCs were under economic stress due to the need to import the food they required to maintain national food security. The food they imported reached, on average, about 12 percent of their apparent consumption by the end of the millennium. While this is not necessarily a negative outcome, as it may be due to domestic production restructuring along comparative advantages, the study showed that throughout that period, the growth in these countries' commercial food import bills consistently outstripped the growth of their GDP, as well as total merchandise exports. The study also revealed that LDCs faced large and unanticipated price 'spikes' that exacerbated their already precarious food security situation. Indeed, it was discovered that variations in import unit costs of many important food commodities contributed to around two-thirds of the variation in their commercial food import bills. Coupled with substantial declines in food aid flows over the same period, these developments have brought about a significant increase in the vulnerability of the LDCs.

In light of the above developments, it seems that the problem of managing the risks of food imports has increased in importance, and is already a major issue for several low income food deficit countries (LIFDCs). The major problem of LIFDCs is not price or quantity variations *per se*, but rather major unforeseen and undesirable departures from expectations, that can come about because of unanticipated food import needs due to unforeseen adverse domestic production developments, as well as adverse exogenous global price increases, such as those that have affected many countries during the 2007-8 period. In other words, unpredictability is the major issue. The purpose of this paper is to explore one way in which low income food deficit developing countries can manage some of these risks facing their economies, in particular those arising from fluctuating and unpredictable world prices for basic foods.

The issue of food import risk for LIFDCs has been discussed extensively for some time, especially after the commodity crisis of the early 1970s Several proposals for international food insurance schemes were put forward in that period (for an early review see Konandreas, et. al, 1978). The issue of financing of food imports by LIFDCs featured prominently in the discussions leading to the World Trade Organzation (WTO) Uruguay Round Agreement on Agriculture (URAA), and gave rise to the "*Decision on measures concerning the possible negative effects of the reform programme on least-developed and net food-importing developing countries"***,** also known as the "Marrakesh Decision" (article 16.1 of the URAA). In the Marrakesh Decision, Ministers recognized "that as a result of the Uruguay Round certain developing countries may experience short-term difficulties in financing normal levels of commercial imports and that these countries may be eligible to draw on the resources of international financial institutions under existing facilities, or such facilities as may be established, in the context of adjustment programmes, in order to address such financing difficulties."

Food import risk, has become again a prominent issue, both internationally as well as nationally, due to the 2007-8 food commodity price boom. The combined increase of basic food commodities prices, such as wheat, maize, and rice, with that of petroleum prices, created a "double squeeze" in many LIFDCs, which are large importers of both food and oil. African countries were more deeply affected (FAO, 2009b, FAO, 2008).

While opinions may differ on the causes of such market situation and its persistence many elements suggest that the issue of food import risks may loom large in the near and medium term future, as several LIFDCs may become increasingly unable to meet commercial food import demands. In addition, given the simultaneous dependence of many of these countries on commodity markets, both on the import and export side, price instability is becoming a problem. As different commodity prices do not move together, the likelihood of high import prices, together with low export prices, is real, and presents new challenges for policy. International food price volatility has not declined, and, if anything, has remained at high levels (Sarris, 2009).

It thus becomes important to examine possible national strategies to deal with the food import risk management problem. A recent review of the policy options (Byerlee, et. al. 2006) stressed the difficulty that many governments face in disengaging from direct interventions, such as stabilization stocks, or discretionary measures such as export bans, but also highlighted the opportunities presented by developments in organised market based instruments. The proliferation of international risk management instruments, such as futures and especially options for basic food commodities, may present opportunities for managing the risks that LIFDCs face in a more organised and cost effective manner. This paper examines how a number of LIFDCs would have fared in the past, had they adopted market based risk management strategies for their wheat and maize imports.

There is scant literature on this topic. An early paper by Faruqee, et. al. (1997) explored hedging Pakistan's wheat imports with futures. The analysis was based on data for one year only, and this opens it to the criticism that the positive results (which favoured the use of futures) could have depended on the specificity of the particular year, or the particular import pattern of that country. Furthermore, Faruqee, et. al. (1997), only used a particular hedging rule, and did not explore alternatives A volume edited by Claessens and Duncan (1993) discussed a number of issues relevant to this work. More recently, Dana et.. al. (2006)

examined the issue of hedging maize imports for Malawi and Zambia using futures and options, and showed that hedging led to a small cost reduction of maize imports.

In this paper we consider wheat and maize imports of several of the major LIFDCs, and examine, within a counterfactual scenario, the possible benefits or losses that could have been incurred, in terms of changes in the variance of unpredictable foreign exchange costs for cereal imports, over a past period of time, that includes the recent price spike period, had they combined their cash imports with easy to apply and transparent hedging strategies, based on futures and options. We use actual import as well as futures and options data to implement the simulations, and explore a variety or rules.

The next section briefly reviews the institutions and the type of agents that may be involved in managing risk associated with food imports in developing countries; while section 3 presents the methodology followed in the analysis, as well as the data utilised. In section 4 we describe the empirical implementation of the exercise, and the hedging rules simulated. The subsequent section explores the relationship between the import prices of the countries selected and the international reference prices, as well as the econometric relation between the latter and prices in the Chicago Board of Trade, which is the largest futures and options market for wheat and maize in the world. Section 6 presents the results of the simulations, while the last section summarizes the results and the policy conclusions.

2. ISSUES RELEVANT TO FOOD IMPORTS OF LIFDCS

Food imports take place under a variety of institutional arrangements in developing countries. A recent study (FAO, 2003) contains an extensive discussion of the current state of food import trade by developing countries. It notes that while in some LIFDCs state institutions still play a very important role in the export of some basic foods, food imports have been mostly privatised in recent years, although with some exceptions, and in some countries, state agencies operate alongside with private importers.

A public sector food importer, namely a manager of a food importing or a relevant food regulatory agency each year faces the problem of determining the requirements that the country will need to satisfy the various domestic policy objectives, such as domestic price stability, satisfaction of minimum amount of supplies, demands to keep prices at high levels to satisfy farmers, or low to satisfy consumers, and many others relevant to various aspects of domestic welfare. Once the domestic requirements have been estimated, the problem is how to fulfil them, namely through imports, or by reductions in publicly held stocks, if stock holding is part of the agency's activities. A related problem is the risk of non-fulfilment of the estimated requirements which may cost domestic social problems and food insecurity. The third problem of such an agent is how to minimize the overall cost of fulfilling these requirements, given uncertainties in international prices and international freight rates, and to manage the risks of unanticipated cost overruns. Finally, but not least, and related to the overall cost of fulfilling the requirements, the agent must finance the transaction, either through own resources, or through a variety of financing mechanisms.

The problems of private import agents are not much different or easier than that of public agents. A private importer must assess with a significant time lag, the domestic production situation, as well as the potential demand just like a public agent, and must plan to order import supplies so as to make a profit by selling in the domestic market. Clearly the private importer faces risks similar to those of the public agent, as far as unpredictability of domestic production, international prices, and domestic demand are concerned, and in addition faces an added risk, namely that of unpredictable government policies that may change the conditions faced when the product must be sold domestically. During the recent food price crisis, surveys documented the adoption of many short term policies in response to high global staple food prices, which created considerable added risks for private sector agents (Demeke et. al. 2009). Furthermore, the private agent may be more credit and finance constrained than the public agent. In fact the study by FAO (2003) indicated that the most important problem of private traders in LIFDCs is the availability of import trade finance.

For the sequel we will not be concerned with the particular institutional character of the agent that does the physical importing of imports. We will refer to an "agent" as the institution, public or private, that does both the actual importing as well as the hedging. This assumption is made in order to allow us to focus on hedging strategies, rather than on the specific institutional arrangements in food importing country. The important point is that the agent will need to plan for imports (in physical or financial terms) ahead of the actual time that imports are needed to be ordered.

Under the institutional arrangements currently in place in most countries it is rather unrealistic to imagine that one single agent manages all imports. However, the analysis that follows applies to any agent that accounts for a fixed share of the total imports, whether it operates on a private or public basis. While it is clear that, unless there is monopoly in importing, there will be no agent that imports a fixed share of the total amount for any country, this is done both because the market information requirements and actions of both private and public agents are the same, but also because for the empirical ex-post simulations we only have data on total commodity imports. Nevertheless, the analysis presented also holds for an agent that would have imported consistently only a "unit" of imports. In any case the objective is to explore whether hedging with futures and/or options offers advantages over simply importing on the spot market.

3. THEORETICAL FRAMEWORK

Consider an agent who needs to plan imports of some basic food into a LIFDC. The present analysis focuses on wheat and maize, which are two of the most widely traded cereals, characterised by well established cash, futures and options markets, and are imported by many LIFDCs. Most countries in this group do in fact import more than just wheat and maize: rice, other cereals, as well as other staples are also common import items. Despite the fact that some short term substitution may take place between the various foods imported (an issue on which we have no information), we will examine wheat and maize imports only and separately, assuming implicitly that the presence of the hedging would not affect the short term import demand of either wheat or maize. Exploring the possibility that risk management affects the amounts of food imports is beyond the objectives of this paper.

The problem posed is the following. In the course of a year, the agent will need to import certain amounts of wheat and/or maize for delivery to the country's border in given months. We shall assume that the agent knows imperfectly the amounts to be imported in every month several months ahead. While in most countries, the total requirements or demand for cereal and other food imports, as well as the likely pattern of imports, will be broadly known some time in advance by traders, as well as other market participants, especially since domestic production conditions normally become clear several months before the onset of the marketing. For this reason, we consider the case in which future import requirements are uncertain.

In order to expose simply the theory behind the hedging rules, assume initially that the agent estimates that at time 1, which is some months ahead of the present time, he will need to import m_1^e units of the basic cereal (wheat or maize), where the superscript e denotes that this amount is the current expectation of import needs at time 1, conditioned on information at time 0. The price the agent will pay when ordering the above amount at time 1 will be denoted as p_1. Define the following variables: f_0 is the futures price of the commodity observed in a relevant organized commodity market at the current period (which is denoted by a subscript 0) for the futures contract expiring at the, or nearest after, the period 1, at which the actual order for imports will be placed. Define by f_1 the price of the same futures contract at time 1. Denote by x the amount of futures contracts (in units of the quantity of the product) purchased at the current period, and by z, the amount of call options contracts purchased also at the current period. The call option contract is written on the same futures contract expiring at or soonest after period 1, and stipulates that if the futures price f_1 at time 1 is above a strike price s, determined at the time of the purchase of the option, then the owner of the call option can "exercise" the option and receive the difference $f_1 - s$ between the futures price at period 1 and the strike price s. The price of the option in the current period is denoted by r_0, whereas the profit from the option in period 1 is denoted by π_1. This profit will be equal to $f_1 - s$ if the option is exercised, and zero otherwise. The profit of the option can be written succinctly as

$\pi_1 = (f_1 - s)l$, where l=1 if $f_1 \geq s$ and l=0 if $f_1 < s$.

Given the above definitions, the foreign exchange cost to the agent at time 1 can be written as follows

$$M_1 = p_1 m_1 - (f_1 - f_0)x - (\pi_1 - r_0)z \equiv \quad p_1(m_1^e + \mu_1) - (f_1 - f_0)x - (\pi_1 - r_0)z \qquad (1)$$

where μ_1 denotes the zero mean prediction error of the current estimate of import needs. It shall be postulated that the agent wishes to minimize the conditional variance of M_1, conditioned on information Ω_0 available at the current time 0.

$$W = \min E\{Var[M_1]|\Omega_0\} \equiv Var_0[M_1] \qquad (2)$$

Where the second identity above just defines the notation for the conditional variance. One could consider a more general concave utility function *u(.)* over *M* but this would not add much to the argument, and it would only unnecessarily complicate the mathematics. The choice of the variance helps focus the argument on the benefits or not of hedging, rather than on the shape of the utility function, and has been the objective utilized by most analyses of hedging in the past, e.g. Benninga, et. al. 1984, and Lence and Hayes, 1994. Analyses using more general utility functions include those of Lapan et. al. (1991), and Sakong et. al. (1993). This objective is not meant to capture the full range of domestic food security objectives in any given country, but only the narrower objective of reducing unpredictability of imports.
The first order conditions for this problem can be written as follows[2] :

[2] The second order conditions hold because of the convexity of M.

$$E\{\frac{\partial Var_0[M_1]}{\partial x}(f_1 - f_0)\} = 0 \qquad (3.1)$$

$$E\{\frac{\partial Var_0[M_1]}{\partial z}(\pi_1 - r_0)\} = 0 \qquad (3.2)$$

To characterize the solution, it is necessary to make assumptions about the relationship between the cash and the futures price. Following Benninga et. al. (1984), the cash price is written as a linear function of the near futures price.

$$p_1 = \alpha + \beta f_1 + \theta_1 \qquad (4)$$

where θ_1 (the basis risk at time 1) is independently distributed from f_1 and has zero mean.

The problem will be solved under the additional assumption that the current futures price is unbiased, namely that the currently observed futures price f_0 is the (conditional) expected value of f_1 , and that the options are fairly priced in the sense that the current option price r_0 is the expected value of π_1. Finally, it is initially assumed that the eventual adjustment to imports μ_1 is a function only of domestic revisions to requirements, due to better domestic information and other domestic considerations, and is not correlated with the prevailing international price at time 1 p_1. This is clearly not strictly correct, as at the time of ordering imports at time 1, the world prices maybe such (for instance high) that may necessitate an additional adjustment of planned imports, over and above that due to domestic factors. Such adjustments are usually the consequence of financial constraints or considerations, and will initially be assumed away for simplicity. In other words ex-ante adjustments of imports to expected world prices are incorporated into m_1^e and subsequent last minute adjustments are initially ignored. We will discuss such ex-post adjustments later.

Given the above assumptions, we can write the conditional variance as a quadratic expression in x and z. The minimization of this expression using straightforward algebra yields the well known results $x = \beta m_1^e$ and $z=0$ (Benninga et. al. 1984; Rolfo, 1980).

One could hypothesize that the importer only has call options available as a hedging instrument, instead of futures, and explore the optimal hedging rule for this case. This is a possible scenario in the real world, as over the counter (OTC) options are available for commodity traders in the absence of organized futures markets. It can then be easily derived from the above equations, that in such a case the optimal hedge ratio with call options only is equal to the following expression.

$$z = \beta m_1^e \frac{Cov(f_1, \pi_1)}{Var(\pi_1)} \qquad (5)$$

As the covariance of f_1 and π_1 , as well as the variance π_1 are conditional on values of f_1 greater than s, the strike price, it can be easily shown that the covariance in the numerator in (5) is equal to the variance of π_1 . Hence the coefficient that multiplies the optimal futures only hedge ratio βm_1^e above is equal to 1. Hence when only options are allowed the optimal options hedge ratio is equal to the optimal futures hedge ratio, and is equal to β times the expected import level. Note that the above results do not depend on the fact that the ex-post imports m_1 is stochastic. This is because the welfare criterion is equal to the variance of M_1 .

If the welfare criterion was a concave utility of M_1 , then the result would be that a mixture of futures and options are the optimal policy (see Sakong et. al. 1993). Notice also that the results do not depend on the magnitude or the variance of the basis at time 1, namely the parameter α and the variance of θ_1 in our notation.

The above results pertain to the case in which the stated objective of the agent is to minimize the unanticipated two-sided variability of the import bills. It may, however, be the case that the agent is interested in minimizing only the unanticipated positive deviations of the import bills, since these deviations are the most detrimental from a food security point as well as a cost perspective. We can deal with this problem by assuming a narrower objective, namely that the agent wishes to minimize the truncated variance of the unanticipated import bill.

To this end, assume that the conditional probability distribution of the import bill M_1 is normal with mean equal to M_1^* and variance equal to $Var_0(M_1)$ as indicated in (2), which for notational simplicity for this discussion we denote as σ^2. Then, using the formulas indicated in Greene (2000, p 899), we can write the mean and variance of the truncated distribution of M_1 for M_1 larger than the average value M_1^*, as follows.

$$E[M_1 \mid M_1 > M_1^*] = M_1^* + \sigma\lambda(\alpha) \tag{6}$$

$$Var[M_1 \mid M_1 > M_1^*] = \sigma^2[1-\lambda(\alpha)(\lambda(\alpha)-\alpha)] < \sigma^2 \tag{7}$$

where the "inverse Mills ratio" parameter λ is equal to the following

$$\lambda(\alpha) = \frac{\phi(\alpha)}{[1-\Phi(\alpha)]} \tag{8}$$

and the parameter α is equal to the standardised deviation of the truncation level (in this case assumed equal to the mean) from the mean of the underlying distribution

$$\alpha = \frac{M_1^* - E[M_1]}{\sigma} = \frac{M_1^* - M_1^*}{\sigma} = 0 \tag{9}$$

where φ and Φ are the standard normal probability density function (pdf) and the cumulative normal pdf.

It is clear, given the above assumptions about the efficiency of the futures and options markets, and given that α is equal to zero, that both the truncated mean as well as the truncated variance of M_1 are functions only of the conditional variance of M_1. If the assumed objective of the agent is to minimize the truncated mean of the import bill deviations, then (6) implies that this objective corresponds to the minimization of the variance of M_1. The same point holds, as can be seen from (7) above, if the objective of the agent is to minimize only the truncated variance of M.

Assume now that there are ex-post adjustments to the estimated import requirements m_1^e. In particular, and to simplify the discussion, assume a simple form of linear ex-post import adjustment as follows.

$$m_1 = m_1^e - e(p_1 - p_1^e) + \mu_1 \quad (10)$$

All that the above does in comparison with the simpler formula for imports indicated in (1) is to incorporate adjustments due to deviations of the ex-post price p_1 from the ex-ante expected price p_1^e, by introducing a parameter *e*. Minimization of the conditional variance of the food import bill M_1, through long but straightforward algebra, implies that the optimal futures hedge is smaller than the previously estimated one, while now the optimal amount of options hedge is nonzero. The relevant formulas are the following.

$$x = \beta(m_1^e - ep_1^e) - e\beta^2 \frac{A - B}{Varf_1 - Cov(f_1, \pi_1)} \quad (11)$$

$$z = -e\beta^2 \frac{-ACov(f_1, \pi_1) + BVarf_1}{Var\pi_1[Varf_1 - Cov(f_1, \pi_1)]} \quad (12)$$

where

$$A = E_0(f_1 - f_0)^3 \quad (13)$$

$$B = E_0[(f_1 - f_0)^2(\pi_1 - r_0)] \quad (14)$$

For an "at the money option", namely when the strike price s is equal to the expected futures price f_0, it can be seen that A=B. For an "out of the money" call option where $s>f_0$, then $A>B$. As the denominators in (11) and (12) are positive, the conclusion is that when there are financial constraints or other considerations which dictate ex-post adjustments of import plans, then the optimal futures hedging rule suggests an amount of futures purchases smaller than the amount dictated by the simple hedge ratio β, and at the same time the purchase of some call options.

The above discussion was made for completeness and to indicate that even with the simple variance criterion, the optimal hedge can involve a mixture of futures and options. Earlier research, adapted to the present framework, concluded that a mixed hedging strategy was optimal under two conditions: when there is uncertainty in the ex-post imports; and when the objective function involves a concave utility (see Sakong et. al. 1993). We have shown that a mixture rule is also optimal when there are budget constraints that may imply ex-post adjustments. Such conditions are quite prevalent in many foreign exchange constrained food importing developing countries. In practice, however, it is very difficult, if not impossible to estimate the ex-post adjustment parameters *e*, as, even for a monopolistic import agent, one usually does not have information on ex-ante and ex-post import amounts. Hence for the empirical ex-post simulations below we will assume a value of *e* equal to zero.

All the above discussion pertains to the problem of hedging future import requirements. However, another possibility for the importer, is to buy at time *t*, *k* months ahead of the actual needs, and store the commodity, until time *t+k*. An agent following such a strategy would need to decide whether to store the physical commodity in the country of destination or in the country of origin. Either way, she/he will need to pay storage cost, and deal with the price uncertainty at the time of the sale. Futures prices reflect the market determined cost of storage of a commodity between the time the futures is bought and the later physical transaction time (times t and $t+k$ in our discussion), albeit this cost can be negative because of backwardation[3]. Hence buying futures can be considered as an alternative to storing, albeit the market determined cost of storage in the Chicago market, may have little to do with the cost of storage (and any implicit backwardation) in the local market. If the agent is well aware of the domestic storage situation, and thinks that the domestic price of storage (including any convenience yield) is lower than the market price of storage as determined in the hedging market (in this case Chicago), then it may indeed be appropriate for her/him to order the commodity now at time t, and then store it in the country of destination and sell it later. However, this is something about which we do not have any information, and do not pursue further here.

4. EMPIRICAL IMPLEMENTATION

The empirical analysis presented here is based on monthly import data; therefore the choice of the countries included in our sample was restricted by the availability of this type of information over a reasonably long time span. Out of the LIFDCs group, we selected eleven countries that have been wheat importers over the past 25 years. For maize data was available for six LIFDCs only (Table 1).

For wheat, the sample of importers accounted for 58 percent of total LIFDCs wheat imports in the period 1980-2008, and for 23 percent of world imports of this product. For maize, the selected LIFDC importers accounted for 49 percent of total LIFDC maize imports and for 6 percent of world imports of the product in the same period. It is worth noting the high share of wheat and maize in the countries' total cereal imports, the percentages reported in the last column, indicate that wheat is the first most important cereal imported, and maize is the second; the two products together account for the vast majority of cereal imports. Moreover, with the exception of large countries like China, India and Pakistan, wheat imports account for a large share of the total wheat consumed domestically, while this is not the case in any of the countries analysed for maize.

The countries included in our sample encompass significant diversity in terms of their cereal import requirements. For wheat, all countries chosen are regular importers, and they include large countries such as China, India, Indonesia, Mozambique, Philippines, and Pakistan, as well as small ones such as Nicaragua and Tanzania. Of these, three large countries, namely China, India and Pakistan have become significant exporters of wheat in the last decade, while continuing to import the product. In the case of maize, most countries are regular importers, except Kenya, Mozambique and Malawi, which have become occasional exporters in the last ten years. A landlocked country such as Malawi is also included. Different types of countries imply different problems for cereal imports. For example, large countries could experience deficits and surpluses in different areas, and this may cause imports as well as exports at different times in the year, if the domestic market cannot arbitrage appropriately, or if it is cheaper to buy or sell abroad; this is observed in some of the countries included in our sample. Occasionally, importing countries may face conditions that would make regular hedging strategies more difficult to implement. Landlocked countries, for instance, may face significantly larger basis risk, given their isolation and the importance of transport costs. The variance of international prices for landlocked countries may therefore constitute a smaller risk compared to the variance of the basis between the international purchasing center and

[3] See Considine and Larson (2001) on risk premiums and backwardation.

their import point. These *caveats* should be kept in mind when interpreting the empirical results.

Most of the actual wheat and maize imports by the countries included in our sample are obtained and priced on the basis of export prices in major exporting countries, such as the US, Australia, and Argentina. Sarris, et. al. (2006) showed, however, that export prices in these markets are closely related, and also that the import unit values of the selected importing countries are significantly related to the reference export prices. Furthermore, it was shown that the various reference prices are closely related among each other. This implies that it is possible to use one of the international reference prices for wheat and maize as a proxy for the import price (minus transport cost) of the importing country. We chose US Gulf prices to represent international references for imports of wheat and maize. Similarly we consider the Chicago Board of Trade as the major hedging market for orders made with reference the Gulf prices. We explore the relationship between the Gulf export prices and the Chicago futures below.

Consider first the problem of hedging the price risk for an amount of wheat and/or maize equal to the hedge ratio times the known amount that will be imported some months ahead. As was shown earlier, ex-post uncertainty about the imports does not affect the hedging rules when the objective is to minimize the conditional variance of import bills. Hence, we shall restrict the empirical analysis to the case when the imports are known or have been estimated precisely ex-ante. Adding uncertainty to imports does not change the overall results of the simulations.

The hedging rules analyzed here imply transactions through futures or options. In terms of data, we employed firstly the actual imports of wheat and maize for all LIFDCs on an annual basis (both calendar as well as crop (July-June) year) from the 1960s. Secondly, we used International Wheat Council (IWC) and FAO data on monthly wheat and maize imports for LIFDCs by origin of imports, since 1995. Given this monthly information, we assumed that for the years in which monthly import data are not available, the pattern of imports, namely the shares of total annual imports imported in each month, is the same as the average pattern of monthly imports from the years in which we have monthly observations. Thirdly, futures and options daily data were obtained from the Chicago Board of Trade (CBOT) from 1986 to 2008. We assumed that all import transactions are done at Gulf prices. This is certainly an approximation, as not all transactions are done on this basis, but it is a reasonable assumption given that all major export market prices are related to these prices. The simulations involve buying futures or call options at a given point in time, ahead of the physical wheat or maize contracting, and selling them at some later point, namely when the actual physical transaction for wheat or maize imports is concluded.

The actions of the agent will aim at insuring the price risk of the physical purchases. It will be assumed that the cash orders for wheat and maize imported in a given month are placed one month in advance. This appears reasonable in light of the norms of the trade, and implies that the prices at which wheat and maize imports will be valued and eventually paid, are prices of one month ahead of the actual physical arrivals at the border.
In order to implement the simulations, given that we have all the daily data available for futures and options, the agent must decide on the rules to follow. Particularly, the following parameters must be specified:

- the day of the year at which the contract (futures or option) is bought;
- what contract to buy (namely for which month to buy a futures or option contract);
- how much quantity to buy of the contract;
- in addition, for options, the decision must be made at what strike price to buy a call option.

We will simulate the following two types of rules (strategies)

Rule 1. Hedging only with futures contracts

Under this set of rules, which are similar to those simulated by Faruqee et al (1997), we assume that the agent buys futures k months in advance of the date when he/she needs to contract the actual delivery. The contract date is assumed to be one month before the needed monthly physical delivery of import, as per the seasonal import needs, which, as indicated above, is assumed to be known. In other words, suppose that according to the needs, the importing agent needs to physically import 100 000 tons of wheat in December. This is assumed to imply that the physical quantities must be ordered one month before. Hence the actual contract for physical delivery in December will have to be placed in November, and this implies that the price at which the transaction and the payment will be made (or the loan obtained), is the November price. Hence the need is for hedging the November transaction and payment. If we assume that $k=4$, then the agent will buy futures contracts for amounts totaling β*100 000 tons in July (namely in the 11-4=7th month of the year). The futures contract at which the futures transaction will be made will be the closest available after the date in which the purchase is needed. In the example here, the actual forecasted transaction is in November, and the nearest traded futures contract is the December one, hence the agent will buy December wheat futures in July, and sell them in November.

In the simulations it is assumed that the agent can buy futures contracts for the exact amount of the product that he/she needs to hedge. This is an approximation, as the actual futures contracts are available only for fixed lump amounts (for instance the standard CBOT wheat futures contract is for 5000 bushels[4] or about 130 metric tons), but it is possible to obtain futures for whatever amount the agent may wish through brokers and traders, for a small extra fee.

Once the month of purchase is agreed, the agent must decide the exact day in the month at which he/she will make the transaction (both purchase and later sale). For the simulations reported below, it has been assumed that this is the day closest to the middle of the month. For sensitivity analysis, we also assumed alternatively that the transactions take place at the beginning of the month, and at the end of the month. However, the results were almost identical, so we report only the results for mid-month transactions. The same strategy is applied month after month. Concerning costs, it is first assumed that the cost of buying or selling futures is 0.15 US $ per ton, just as in Faruqee et. al. (1997). In addition it is assumed that each futures transaction requires the deposit of a 5 percent margin. We assume that there is an interest cost on this margin valued at a rate equal to US base interest rate, which changes every month.(published by the IMF) This cost is calculated over the period of the hedge.

[4] In the CBOT one could purchase also mini-wheat and mini-corn contract which trade in 1000 bushel units.

Rule 2. Hedging with options

The simulation under this scenario will involve examining how the agent in the specific LIFDC would have fared if he/she had hedged past imports only with call options.

All the conditions stated above for futures, concerning the dates at which the contracts are bought and the dates of expiration, also hold for the simulations with call options. The only difference is that in this case the strike price also has to be determined. The rule here is that the strike price is parameterized as *(1+α)* $p^f_{t,t+k}$ where $p^f_{t,t+k}$ denotes the futures price observed in month t for the contract expiring at or in the nearest month after the period $t+k$, when the actual transaction will be made. The parameter α is the proportion above this future price for which insurance is sought. Hence if α =0.1, the (out of the money) call option bought implies that if the future price observed at the time of ordering the grain import, is above the strike price - which as per the option specification is 1.1 times the current future price - then the difference between the actual higher futures market price and this strike price will be paid to the buyer of the option, namely the agent. Based on industry information, we assume a transactions cost for buying the call option equal to 4.5 percent of the option price.

An example is in order. Suppose that in a given trading day of the 7th month of the year, namely July 15th, the agent purchases a call option with □ = 0.1 and k = 4. This means that the call option expires in November (month 7+4), when the actual contract for the physical wheat or maize shipment that is to be delivered in December will be made. Suppose that on July 15, the December future is quoted at 90.9 ($ US per ton, although the actual quoted price is in cents per bushel). With □ = 0.1 the desired strike price at which the call option will be bought is P_s = 100=(1.1 times 90.9) $ US. As options are not available for all strike prices, the strike price at which the call option is bought is the nearest to the desired price of 100 among those quoted. Assume that this is 98.0 dollars and that the cost of buying this call is PR= 12.0 dollars. The calculation of the gain from the option purchase examines the December future price on November 15 (we take the settlement price on November 15 or the nearest trading day to November 15). Suppose that this price has moved upward beyond expectations, to P_{NF} = 120 US $. In this case the option will be exercised, and the net gain, taking into account the transactions cost, will be N= (120 - 98) - 12 -0.045*12= 9.46 $ US. Suppose now that price growth expectations have not fully materialized, so that the December future on November 15th has only reached P_{NF} = 95. In this case the option will *not* be exercised, and the net loss accounted for will be N= - 12-0.045*12= -12.54 $US.

Given that the objective of the hedging exercise is to reduce the conditional variance of the import bills, an ex-post measure of success of the hedging strategy, as per the theory exposed earlier, is the variance of the unpredictable changes in the values of imports with and without hedging. For each period we first compute for each t the unexpected change in import cost

$$M_{t+k} - E(M_{t+k,t}) = \{p_{t+k}m_{t+k} - E(p_{t+k,t})m^e_{t+k}\} \tag{15}$$

and then compute the variance (or standard deviation) of the changes in (15) over a given historical period. When the same imports are hedged with futures, the unpredictable change in the import cost is equal to:

$$M_{t+k} - E(M_{t+k,t}) = [p_{t+k}m_{t+k} - E(p_{t+k,t})m^e_{t+k}] - \beta(f_{t+k} - f_t - \tau_f f_t - gi_{t,t+k} f_t)m^e_{t+k} \tag{16}$$

where τ_f denotes the unit transactions cost of buying a futures contract, g is the margin requirement (assumed 5 percent) and $i_{t,t+k}$ denotes the interest charge on the margin over the period t to $t+k$. Note that we neglect possible margin calls during the period of holding the futures contracts. When prices fall in the course of holding a long futures contract, the agent will have to post additional margin, and this may create liquidity and financing problems with the agent. We ignore this aspect of futures hedging, albeit for cash constrained LIFDCs this aspect maybe quite important.

Finally, when the same imports are hedged only with call options, the unpredictable change in the import cost is equal to:

$$M_{t+k} - E(M_{t+k,t}) = [p_{t+k}m_{t+k} - E(p_{t+k,t})m^e_{t+k}] - \beta(\pi_{t+k} - r_t - \tau_o r_t)m^e_{t+k} \qquad (17)$$

where π is the actual realized profit on the option contract (namely equal to $f_{t+k} - k$, if this quantity is positive at time $t+k$, and zero otherwise) τ_o denotes the unit transactions cost of buying a call option contract. As we discussed earlier, the ex-ante uncertainty about the precise value of the eventual actual imports does not affect the hedging rules. Hence for the simulations the expected values above will be set equal to the actual observed values of imports.

In order to implement (15)-(17) we need to estimate the conditional expectation of the future cash price. Under the assumption (4), the conditional expectation at time t of the cash price at time $t+k$ is a linear function of the conditional expectation of the nearest futures price at time $t+k$. Under the assumption that future markets are unbiased, this latter expectation is equal to the price of the futures contract that expires at or near time $t+k$, observed at time t. Hence we can use the following expression for estimating the conditional expectation in equations (15)-(17)

$$E(p_{t+k,k}) = \alpha + \beta f_t^{t+k} \qquad (18)$$

where f_t^{t+k} is the price at time t of the futures contract expiring at or nearest after period $t+k$, and α, β are parameters to be estimated empirically (see next section).

The simulation exercise compares the standard deviations of the normalized expressions in (15)-(17). The normalization is obtained by dividing the expression in (15)-(17) by the average unhedged import bill for the period under investigation, namely the average of the magnitudes $p_t m_t$. This normalization is the same in the case of unhedged and hedged imports, so that whatever differences are estimated in the variability measures of the above expressions are due to the application of the futures and options hedges and not the denominator. It should be underlined that the monthly import values are approximate and indicative wheat and maize import bills, built up on the assumption, discussed above, that the price paid by an importing country when importing from the US or any of the other main exporters is the Gulf price. This is, of course, an approximation, as there may be significant transport and other country specific transactions related price difference between the Gulf price and the border price in the country, but, as actual transactions and monthly cif price data is unavailable, it can serve at least as an indicative number. If the transport costs and any other country specific costs are independent of the world market price, which we assume is represented by the Gulf price, then all the previous discussion remains intact, but the amount of the actual import bill that is hedged in our analysis would be a fraction, different for each country, of the total actual import bill. Our results and the analysis do not take into consideration these latter costs, whose variability is in fact assumed to be orthogonal to that of world prices. However, this may not be the case in some periods of price spikes, depending on the source of the spikes. In point of fact during the recent price boom of 2007-8, the Baltic freight rate index, which is a representative index of bulk freight rates, has been highly correlated with commodity prices, but it is not clear whether this is a recent and only temporary phenomenon.

5. PRICE RELATIONS BETWEEN GULF EXPORT PRICES AND CHICAGO BOARD OF TRADE PRICES

In this section we firstly examine whether the Chicago Board of Trade futures prices - and hence those of the related options - are indeed effective reference prices for hedging wheat and maize imports of the selected developing countries, under the assumption that imports are based on Gulf prices. Secondly we need to examine whether the CBOT futures prices can be employed as expectations of the reference cash price, as per equation (18).

We need to start from the source of imports for wheat and maize of the countries under consideration. Analysis of wheat import data by source for the studied countries reveals that the bulk of wheat imports is obtained from three sources, namely the US, Australia, and Argentina. Given this observation we consider, the monthly US Gulf price for hard winter ordinary no 2 wheat, and the monthly export unit values for Australia and Argentina as world import reference prices for wheat; these are reported in the IMF International Financial Statistics. As far as maize is concerned, the major source of imports of the studied countries is the US; therefore we consider the monthly US Gulf yellow maize price as a reference price for maize. All series are transformed into common units, namely $US per metric ton.

Time series analysis involving co-integration tests, between the three world wheat reference prices reveals that they are move closely together (Sarris et al, 2006). Hence we can choose one of the three world wheat reference price as the representative price for wheat imports, and we choose the US Gulf price.

The next issue concerns the relationship between the Gulf prices and CBOT prices, as it is this that will dictate the hedge ratio, as well as the form of the function for price expectations. As futures do not exist for all months, the CBOT price that was considered as the corresponding reference futures price for the Gulf market, was assumed to be the one for the nearest available futures contract.

To analyze the basis risk of the Gulf prices, time series price relations were analysed with the econometric approach followed in Rapsomanikis *et al.* (2003). First, the dynamic properties of the series involved are investigated, through standard tests for the presence of unit roots, aimed at understanding their order of integration. Two different tests were applied: the Augmented Dickey-Fuller (ADF) test, and the Phillip-Perron (PP) test both including a time trend and a constant term. Both tests suggest that the series for monthly Gulf prices as well as CBOT near futures are integrated of order one, or $I(1)$.

Given that the results of the order of integration suggest that the monthly time series are all integrated with the same order, for each price, the following Auto Regressive Distributed Lags (ARDL) model was estimated between cash prices p and nearest futures prices f:

$$p_t = a + \tau T + \sum_{j=1}^{J} \beta_j p_{t-j} + \sum_{k=0}^{K} \gamma_k f_{t-k} + e_t \qquad (19)$$

in which *J* and *K* were chosen through the minimization of the Akaike information criterion, and *T* represents a time trend. All prices in (20) are in level form. Logarithmic versions were also estimated, and were also robust, but it turned out that the level version estimates provided much better predictive power for the cash price model in (18). The presence of a long run relationship between *p* and *f* was tested by computing the parameters of the long run relation between Gulf and CBOT near futures prices, akin to the theoretical equation (4), namely $p_t = \lambda_0 + \lambda_1 f_t + u_t$. This relation is derived from (19) under the assumptions that $p_t = p_{t-k} \forall k$ and $f_t = f_{t-j} \forall j$. These assumptions imply that

$$\lambda_0 = \frac{a}{1-\sum_j \beta} + \frac{\tau T}{1-\sum_j \beta} \;; \qquad \lambda_1 = \frac{\sum_k \gamma_k}{1-\sum_j \beta_j} \text{, and} \qquad u_t = \frac{e_t}{1-\sum_j \beta_j} \qquad (20)$$

In order to take into account the adjustment taking place around the long run equilibrium, the ARDL model (20) has also been estimated in the corresponding Error Correction (ECM) specification, which is as follows:

$$\Delta p_t = a + \delta T + \rho [p_{t-1} - \lambda_1 f_{t-1}] + \sum_{j=1}^{J} \beta_j^* \Delta p_{t-j} + \sum_{k=0}^{K} \gamma_j^* \Delta f_{t-k} + h_t \qquad (21)$$

The above relation, in which the long run parameter $\square_1$.is the same as the one calculated from the ARDL model in (20), allows one to distinguish between the short run adjustment parameter $\rho = (1 - \sum \beta_j)$ known as the ECM coefficient, and the long run parameter $\square_1$. Estimates for these two parameters, as well as parameter λ_0 in (20) are reported in Table 2 for wheat and maize[5].

For both wheat and maize, Gulf prices appear highly correlated to the Chicago future prices, given that the $\square_1$ coefficient are highly significant and very close to 1. The ECM short run parameters, also appear to be quite large, suggesting that any departures from the long run relationship are reflected quite rapidly in subsequent price changes. In other words, the long run relationship is fairly robust. Altogether, these results indicate that there is a considerable, albeit not perfect, transmission of price signals between the Chicago future market and the average prices actually paid for ordering wheat and maize for imports into the selected countries. In turn, this allows us to hypothesize that the Chicago futures market could be a viable trading marketplace in which risk in import prices may be hedged by the selected countries.

The econometric time series models employed here is dynamic; the long run relationship between the reference export prices and the CBOT prices, therefore, is not perfect in any one period, as lags in the adjustment are considered. This implies, as equation (21) clearly shows, a more complicated relation between cash and futures prices than (4). This, in fact would

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[5] The estimated values of the trend parameter τ was very small and insignificant, hence did not make any difference in the estimates of λ_0

imply a more complicated optimal hedging strategy than one based on simple relations like (4), as is done here, and as was done by Faruqee et al. (1997). For instance it may imply that the hedging for price risk for given desired import shipment may need to be done by allocating different portions of the desired hedged quantity to several futures contracts.

The definition of an optimal hedging dynamic strategy based on the dynamic relation between the import price of the selected countries and the CBOT prices is, however, beyond the purpose of this article. Nevertheless, since the steady state relationship in (4) appears to be fairly robust, the deviations in the optimal strategy from one based only on the long run relationship are expected to be small. Moreover, if the unanticipated variance is reduced under the static rules simulated here - as the empirical results indicate - then it is to be expected that more complicated rules, based on a more accurate assessment of the dynamics will reduce it even further. In the simulations reported below the assumption is made that the value of the hedging parameter β (re equation (18)) is equal to the value of the parameter □$_{\iota}$ as indicated in table 2, and the value of α is equal to the value of λ_0 in (20), and is also indicated in table 2.

6. RESULTS OF HEDGING STRATEGIES WITH FUTURES AND OPTIONS

Before we discuss the ability of futures markets to provide appropriate hedging media for staple food imports, we examine the behaviour of prices in both cash and futures markets. Table 3 presents the average unanticipated changes in the cash and futures prices of wheat and maize over a period of k months before time t, and over the periods (1985-7 to 2005-12), the recent upheaval 2006-1 to 2008-12 and for the two periods combined. It also presents the standard deviations of these prediction errors. Several observations are in order. First the ability of a simple linear formula like (18) to predict the subsequent actual cash price is quite good on average in "normal" periods, even some months in advance. Notice that the average percent forecast errors during the period 1985 to 2005 for k=2 and k=4, were around 1.2 percent for wheat and 3.6 percent or less for maize. For six months prediction, the average forecast errors were similar to those for k=2 and 4 for wheat but larger for maize at 5.1 percent. Notice that during the period of high prices, namely the period 2006-8, the ability of simple formulas like (18) to predict the eventual cash price of wheat deteriorated, but surprisingly it was better for maize. This performance is mirrored in the ability of the futures price for forecast the subsequent futures price. The forecast statistics for average unpredictability of the futures prices are quire similar to those of the cash market statistics.

Turning to the variability of ex-ante predictions, the last two sets of rows in table 3 exhibit the standard deviation of the percent forecast errors of the expected cash and the futures prices. It can be seen that these are considerable and increase with the length of time before the actual purchase, as would be expected. For instance for k=2, namely for two months advance, the average percent standard deviation for the cash and futures price of wheat over the period 1985-2005 is around 8-9 percent. As the 95 percent confidence interval for predictions under normality is about two standard deviations, these numbers imply that even within 2 months before actual ordering, the price uncertainty is in the vicinity of 16-18 percent of the currently observed cash price. This is considerable and basically indicates the variability and unpredictability in these markets, even for short planning periods. For k=4 the same standard deviation increases to 10.5-11 percent for wheat and 13 percent for maize. For k=6 the numbers jump to about 13 percent for wheat and 15 percent for maize. Notice, however, that during the food price increase period of 2006-8, the unpredictability increased considerably, with the standard deviations of the prediction errors in both cash and futures markets increasing by 100 percent or more in some cases from the averages of the more normal twenty year period of 1985-2005

Concerning simulations we first present the statistics of the measures in (15)-(17) when the value of imports in equal to 1, namely when only one ton of imports is made consistently every month over the period of the simulation. The rationale for exhibiting these statistics is to indicate separately the variability of the price factors from the variability of imports in contributing to the overall unpredictability of the import bills indicated in (15)-(17). Table 4 exhibits the relevant statistics in the form of standard deviations of the relevant percent changes.

It can be seen from table 4 that hedging with futures only reduces considerably the unexpected price variability of import prices for both wheat and maize and for all periods simulated. The reductions are substantial, and for the recent spike period as large as 72 percent. The reason for which the values of the standard deviations in the case of futures hedging (namely the middle set of rows) are not much different for the different values of k is that the value of the hedge ratio β is close to one as seen in table 2, and hence as per formula (18) the expression (16) reduces largely to the difference between the cash and futures price at time t, and does not include in any substantive way the ex-ante futures price, and hence the resulting expression is more or less the same irrespective of the value of k (of course some variability due to the different margin cost for different k's remains but it is small).

As far as the variability of the unexpected price changes when options are used exclusively, the last three rows of table 4 indicate that for wheat the reductions are still substantial for all periods of simulations and for all values of k, but not as large as the ones for futures only (as would be expected from the theoretical section, since options are not the optimal strategy). For maize the results are more mixed, with reductions (smaller than with futures only) in the normal period before 2006, but with increased variability in the three year "price spike" period 2006-8. This maybe due to the particular behaviour of maize options prices. Table 5 exhibits the average of the ratios of the price of the call option in Chicago to the price of the underlying future at which the option is written for different periods of time. It appears that for wheat this ratio was on average less than 1 percent during the whole period up to 2007 and for all values of k, but then it increased steadily during the period 2006-7, and jumped considerably in 2008 for all values of k, probably as a result of extreme price unpredictability and underlying uncertainty about future price movements. For maize the ratios appear to have been considerably larger for the whole pre-crisis period and then just as in wheat they increased steadily in the years 2006, 2007 and then jumped to very high values in 2008. It seems that there is generally more uncertainty and unpredictability in the maize market compared to the wheat market, and that something very particular affected the Chicago maize market in the peak of the crisis period, namely in 2008.

We now turn to the unpredictability of the import bills. Table 6 indicates the unanticipated normalized standard deviations of monthly wheat import bill changes with and without hedging with futures only. The results cover as in the previous tables two periods, namely the period 1985-7 to 2005-12, namely before the grains price spike, the spike period 2006-1 to 2008-12 and both periods combined. Table 7 indicates the same but when hedging with at the money options only is employed.

The results in table 6 indicate that for all the countries analyzed there seems to be substantial reductions in import bill unpredictability for all periods and for all values of k, when imports are hedged with futures. The only exception seems to be India for which the unpredictability with futures and for k=4 seems to have slightly increased. This seems an oddity and is not due to the behaviour of the cash or futures prices, as these affect all countries in the same fashion. This phenomenon maybe due to the particular pattern of imports of India during the crisis period. In fact wheat imports of India during the last year of the crisis period, namely 2008, declined to about 10 percent of the average wheat imports of the previous two years. Furthermore, India seems to have exhibited in the past a marked seasonal pattern of wheat imports, with low imports early in the calendar year, peaking in the middle of the year, and then declining during the rest of the year. It maybe that the combination of the particular price pattern of wheat during the crisis, in combination with the particular import pattern of India during the crisis generates this result.

The reductions in unpredictability of import bills seem to be larger during the crisis period of 2006-8 compared to the earlier period for all countries and values of k, with the notable exceptions of China and India.

Table 7 indicates that if hedging was done with options only, the unpredictability of wheat import bills would have also decreased considerably for all countries and periods, again with the only exception being India for the crisis period and for k=4. The percent reductions in unpredictability are smaller with options (as expected from theory) in all cases. The reductions seem to be larger for the crisis period for all countries except China and India.

Tables 8 and 9 exhibit the same results for maize importers that are LIFDCs. In the case of hedging with futures only the unpredictability of maize import bills is unambiguously decreased for all countries simulated and for all periods as well as values of *k*. In almost all cases (Indonesia being the exception by a small amount for *k*=4) the percent reduction in unpredictability is larger during the crisis period. The results when hedging with options, indicated in table 9, suggest that during the pre-crisis period, there was also a reduction in import bill unpredictability, albeit not as much as one could obtain with futures hedging only. However, during the crisis period the unpredictability would have been higher for most of the maize importing countries had they hedged only with options. This is consistent with the very high maize option prices during the peak of the crisis, exhibited in table 5, which suggested extreme unpredictability of the prices during that period.

The above results pertained to the objective of the paper, namely to reduce the unpredictability of import bills. However, most LIFDCs are also interested in the overall absolute magnitude of the import bills. Hence, apart from the predictability or not, an important policy question is whether the reduction in unpredictability entails a cost in terms of higher food import bills. Reducing the average cost of food import bills was not the objective of the paper, as there are many other policies, national and international, that could be considered to do this (for instance a higher degree of self-sufficiency). Nevertheless, and to examine whether hedging entails higher import bills we also exhibit the simulated changes in actual average ex-post import bills that would have occurred had the countries simulated hedged with futures and at the money options. Table 10 exhibits the average monthly wheat import bills for the countries simulated over the periods 1985-7 to 2005-12 and 2006-1 to 2008-12, and the percentage differences of the simulated import bills when futures or at the money options hedging would have routinely applied to those monthly imports. Table 11 does the same for maize.

From table 10 it can be seen that for most LIFDCs, during the normal pre-crisis period of 2005-2006, routine hedging with futures would have affected only slightly the average size of the countries' wheat import bill. The simulated changes range from a minimum of -1.8 percent for China (for *k*=6) to a maximum of 5.1 percent for Tanzania (also for *k*=6) for most countries the changes are between -1 and 3 percent. For the crisis period of 2006-8 the simulations show that most countries would have reduced their average wheat import bills, but there are cases where the import bills of some countries would have been higher. The changes range from a minimum of -9.4 percent (Sudan for *k*=6) to a maximum of 7.6 percent (Pakistan for *k*=2). However, the simulated increases in the wheat import bills pertain to only 1-3 countries depending on the value of *k*, while all other countries would have reduced their average wheat import bills during the crisis period. The results suggest that the substantial reductions in wheat import bill unpredictability that were discussed earlier do not appear to be earned at the expense of much higher import bills.

Turning to hedging with at the money options, the simulated changes in the average cost of wheat import bills during the "normal" period seem to be more pronounced than those exhibited under futures hedging. The simulated changes during this period range from a minimum of -3.9 percent (china for *k*=6) to a maximum of 9.5 percent (India for *k*=6). During the crisis period, however, almost all countries indicate considerable reductions in their wheat import bills (the exception is Pakistan), ranging from 0.1 percent (Tanzania for *k*=2) to as much as 14.6 percent (china for k=6). This suggests, that while hedging with options leads to a smaller reduction in unpredictability compared to hedging with futures, as illustrated above, it may lead to considerable reductions in actual import bills during a spike period.

Turning to maize, table 11 presents the same results as for wheat but this time for maize imports. For the normal pre-crisis period the simulated changes in the maize import bills when hedging with futures only in most case appear to be higher than those without hedging. However, during the crisis period there could have been substantial reductions in the maize import bills for almost all countries. The reductions could have been as high as 18.9 percent (Malawi for *k*=6). The only exception is Mozambique for *k*=2 where hedging with futures during the crisis would have resulted in a slight increase in maize import bills of 1.3 percent.

Turning to hedging with options only, the results are mixed, but for most countries they suggest that the average import bill for maize would have been higher both during the normal period as well as the crisis period. The exception is Malawi and Tanzania, where the results suggest that hedging in Chicago options would have reduced the average maize import bill during the crisis by significant amounts but only for specific values of *k*, namely months before ordering the imports.

7. CONCLUDING REMARKS AND IMPLICATIONS FOR IMPORT STRATEGIES

The results of the simulations suggest that hedging wheat and maize imports by agents in several Low Income Food Deficit Countries using futures and options in the CBOT exchange may be a viable strategy to reduce the unpredictability of basic food import bills. The scope for the reduction in unpredictability in normal periods seems larger when hedges are made with futures compared to hedging with options only. The reason for this result appears to be that prices in the Chicago futures market for wheat and maize appear to be highly correlated with the major export markets, and also because futures prices in Chicago appear to be unbiased, and hence incorporate most of the available trade information. The simulated reductions in unpredictability are quite substantial for both wheat and maize for most countries. Despite the cost of hedging with futures and options, it appears that overall the actual cost of food imports does not increase because of the addition of hedging as part of the food import strategies.

An important result is that reductions in unpredictability were quite significant during the recent crisis period and larger than in normal times. This suggests that during price spike periods, considerable advantage in import bill management can be obtained by the use of organized futures and options markets.

As organized futures and options markets in the CBOT, seem to be quite efficient, no agent can be expected to make profits in the long run from applying hedging rules of the types simulated here. Hence the motivating force for hedging can be predictability and improved planning, and not profitability, which would rather be the motivation of private speculators, but not of financial or import planners. Nevertheless, it was shown that there can also be benefits in terms of reductions in average cost of imports, albeit it is not clear whether this results is due to the particular history of prices observed, or can be generalized.

Of notable interest is the result that hedging with options could have reduced considerably not only the unpredictability but also the average cost of wheat import bills during the recent crisis, albeit not so for maize imports. The reason for this asymmetry may have to do with the particular workings of these markets, with the Chicago wheat market being perhaps more representative of the global wheat market than maize, and the fact that market uncertainty about subsequent prices reached unprecedented levels for maize at the height of the crisis. As such spikes are one-off events with their own particularities, which are unlikely to replicate in the same form, this may not be unexpected.

Apart from the reduction in unpredictability, there may be benefits deriving from the insurance through hedging such as, for instance, that the overall quantity of imports may increase, thus resulting in higher domestic food supplies, and possibly improved domestic food security.

The existence of significant transmission of price signals for the commodities chosen among the major export markets and CBOT, confirmed that the CBOT offers a viable hedging market for wheat albeit less so for maize imports for many of the countries considered.

A number of *caveats* are in order when considering the results of the simulations. Firstly, given the importance of the countries involved in global wheat and maize imports, one may question whether their involvement in the CBOT may influence the price determination process in the exchange. Secondly, as mentioned, the simulations are based on a comparison with purely commercial transactions in the spot market, whereas it is known that for many of the selected countries, concessional transactions are a considerable share of cereal imports. Thirdly, it may be that a dynamic hedging strategy along with the seasonal import pattern, and possibilities for substitution among food products, may make a difference to outcomes.

Finally, it was pointed out that these rules will reduce neither the risks involved in transactions costs, or transport costs, nor the risks involved in foreign exchange. Some of these risks may be substantial in developing countries, and since they cannot be diversified through the rules simulated here, they may diminish the effectiveness of hedging. Foreign exchange risk can be dealt with in foreign exchange futures and options markets, and it may be possible to hedge also some of the transport costs in organized markets. Also, it might be possible to hedge some of the possibly large basis risk of some countries, if there are organized regional exchanges, as it may be the case in some of the countries included in our sample, such as India, China and South Africa. However, it is not clear that such exchanges offer good hedging medium for imports that must be purchased internationally. These issues are certainly important, and call for more extensive research, that might involve additional products and markets.

The implications in terms of development policy are that many LIFD countries may benefit from encouraging their main import agents to institute more predictable food import expenditure schemes based on the hedging rules of the type suggested in this paper. Even if the average monetary benefits are small in the long run, the indirect benefits from increased predictability can be large in terms of securing enough food for those in need, and hence the assurance for many developing countries that they will not have to reallocate development funds to deal with short term food crises. This, in turn could lead for a more orderly pattern of public investments and hence potentially faster growth.

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Table 1 Countries selected for the empirical analysis

Wheat importers

	Average country wheat imports (1980-2008)	Share in LIFDC wheat imports (1980-2008)	Share in World wheat imports (1980-2008)	Share of wheat imports in domestic utilization (1980-1990)	(1991-2008)	Average country cereal imports (1980-2008)	Share of wheat in country's cereal imports (1980-2008)
	(000 tonnes)	*(. percentage*			*. . . . .)*	*(000 tonnes)*	*(. . percentage. .)*
Bangladesh	1622	3.9	1.6	59.5	57.7	2285	71.0
China, Mainland	6772	16.3	6.6	12.5	3.7	8813	76.8
Egypt	6839	16.4	6.7	73.2	53.2	9756	70.1
India	1122	2.7	1.1	2.5	1.7	1359	82.6
Indonesia	3137	7.5	3.1	101.2	103.7	4844	64.8
Mozambique	210	0.5	0.2	95.1	102.5	589	35.6
Nicaragua	98	0.2	0.1	105.2	92.8	220	44.3
Pakistan	1345	3.2	1.3	6.3	8.5	1368	98.3
Philippines	1956	4.7	1.9	103.4	100.2	2963	66.0
Sudan	772	1.9	0.8	70.3	68.4	960	80.4
Tanzania	177	0.4	0.2	44.8	85.4	370	47.9
Total of above	**24049**	**57.8**	**23.4**			**33527**	
Total LIFDC	**41638**	**100.0**	**40.5**			**62846**	
World	**102786**					**220716**	

Maize importers

	Average country maize imports (1980-2008)	Share in LIFDC maize imports (1980-2008)	Share in World maize imports (1980-2008)	Share of maize imports in domestic utilization (1980-1990)	(1991-2008)	Average country cereal imports (1980-2008)	Share of maize in country's cereal imports (1980-2008)
	(000 tonnes)	*(. percentage*			*. . . . .)*	*(000 tonnes)*	*(. . percentage. .)*
Egypt	2885	32.9	4.1	28.7	38.0	9756	29.6
Indonesia	506	5.8	0.7	1.2	7.5	4844	10.5
Kenya	414	4.7	0.6	4.8	19.4	911	45.5
Malawi	127	1.4	0.2	2.1	9.5	174	72.9
Mozambique	219	2.5	0.3	40.1	18.1	589	37.1
Tanzania	94	1.1	0.1	5.5	2.9	370	25.4
Total of above	**4245**	**48.5**	**6.0**			**16644**	
Total LIFDC	**8760**	**100.0**	**12.5**			**62846**	
World	**70314**					**220716**	

Source: Authors' calculations

Table 2 Transmission between international reference prices (at the US Gulf) and the nearest CBOT futures price for wheat and maize (monthly data - sample: April 1985 - Jan 2009)

	dependent variables		*PWUS*	*PMUS*
regressor				
nearest future price at CBOT	λ_0	coefficient	9.86	6.68
		t-ratio	5.17	5.29
	λ_1	coefficient	0.99	1.01
		t-ratio	71.99	81.15
	ρ	coefficient	-0.64	-0.69
		t-ratio	-23.75	-26.37
PWUS =US Gulf no.2 wheat price				
PMUS = US Gulf maize price				
λ_1 and ρ are the long run and short run coefficients, respectively				

Source: Authors' calculations

Table 3 Average unanticipated prediction errors of cash and futures prices, coefficients of variation of cash and futures prices, and standard deviations of percentage prediction errors of cash and futures prices for wheat and maize on CME/CBOT over 1985-2008

		1985-7 to 2005-12	**2006-1 to 2008-12**	**1985-7 to 2008-12**	**1985-7 to 2005-12**	**2006-1 to 2008-12**	**1985-7 to 2008-12**
		Wheat			**Maize**		
Average Gulf price (USD/ton)		143.3	257.6	157.6	105.4	169.4	113.4
$(P_t\text{-}E_{t-k}(P_t))/P_t$ (percent)	k=2	-1.1	1.5	-0.7	-1.6	2.8	-1.0
	k=4	-1.2	1.6	-0.9	-3.6	2.7	-2.8
	k=6	-1.0	4.2	-0.3	-5.1	4.5	-3.9
$(F_t - F_{t-k,t})/P_t$ (percent)	k=2	-0.3	0.9	-0.2	-1.0	1.4	-0.7
	k=4	-1.3	1.0	-1.0	-2.9	1.3	-2.4
	k=6	-1.9	3.5	-1.2	-4.4	3.0	-3.5
CV of Gulf price (percent)		18.9	30.3	33.7	19.5	29.3	29.5
CV of CBOT near futures price		17.1	32.2	31.8	19.2	30.9	28.9
Stdev of $(P_t\text{-}E_{t-k}(P_t))/P_t$) (percent)	k=2	8.3	16.1	9.6	9.3	15.4	10.4
	k=4	10.9	22.6	13.0	12.9	24.1	14.9
	k=6	13.3	26.0	15.6	14.9	27.8	17.3
Stdev $[F_t -(F_{t-k,t})/P_t]$ (percent)	k=2	8.0	16.2	9.4	9.3	15.9	10.4
	k=4	10.4	22.6	12.6	12.8	25.0	14.9
	k=6	12.9	25.6	15.2	14.7	28.7	17.2

Source: Estimated by authors

Table 4 Variability of unanticipated cash price changes and hedged price changes for wheat and maize 1985-2008

		1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12
		Wheat			**Maize**		
Stdev of $(P_t - E_{t-k}(P_t))/\ P_t$ (percent)	k=2	8.3	16.1	9.6	9.3	15.4	10.4
	k=4	10.9	22.6	13.0	12.9	24.1	14.9
	k=6	13.3	26.0	15.6	14.9	27.8	17.3
Stdev of $[(P_t - E_{t-k}(P_t)) - \beta(F_t - F_{t-k,t} - \tau_f - gi_{t-k,t})]\ /P_t$ (percent)	k=2	5.2	7.3	5.5	4.1	4.8	4.2
	k=4	5.3	7.3	5.6	4.1	4.8	4.2
	k=6	5.3	7.3	5.6	4.1	4.8	4.2
Stdev of $[(P_t - E_{t-k}(P_t)) - \beta(F_t - (S_{t-k,t,a=0} + (1+\tau_o)r_{t-k}))]/\ P_t$ (percent)	k=2	6.5	10.9	7.3	6.5	21.9	10.6
	k=4	8.3	13.5	9.1	8.6	29.2	13.9
	k=6	10.1	14.7	10.8	9.7	35.7	16.3

Source: Authors' calculations

Table 5 Average ratio of the price of at the money wheat and maize options in CBOT to the futures price on which the option is written at various advance periods (k's) (percent)

	1985-7 to 2005-12	2006-1 to 2006-12	2007-1 to 2007-12	2008-1 to 2008-12	1985-7 to 2005-12	2006-1 to 2006-12	2007-1 to 2007-12	2008-1 to 2008-12
	Wheat				**Maize**			
k=2	0.37	0.61	0.94	8.67	3.29	5.82	8.87	28.58
k=4	0.48	0.64	0.74	9.08	4.63	7.13	7.59	44.01
k=6	0.52	0.68	0.69	6.65	5.70	7.91	8.46	46.49

Source: Authors' calculations

Table 6 Unanticipated normalized standard deviations of monthly wheat import bill changes with and without hedging with futures

	Unanticipated normalized standard deviation of monthly import bill changes without hedging			Unanticipated normalized standard deviation of monthly import bill changes, when hedged with futures only			Percent difference from unhedged		
	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12
	k=2			k=2			k=2		
Bangladesh	10.0	21.1	16.4	6.0	5.9	6.2	-40.5	-72.1	-61.8
China	11.1	20.3	11.9	5.2	11.2	5.5	-53.3	-44.9	-53.3
Egypt	9.4	21.5	15.5	5.3	6.0	5.8	-43.1	-72.0	-62.6
India	24.3	27.7	41.3	14.0	25.7	35.4	-42.3	-7.2	-14.4
Indonesia	10.9	18.7	17.0	6.8	6.8	7.1	-37.8	-63.8	-58.5
Mozambique	9.4	15.0	14.9	6.9	7.9	8.4	-26.1	-47.2	-43.4
Nicaragua	13.8	23.6	18.8	7.0	8.1	7.7	-49.2	-65.6	-58.9
Pakistan	14.9	48.2	30.6	5.9	4.8	5.8	-60.1	-90.0	-81.2
Philippines	10.0	18.4	14.7	6.1	6.6	6.6	-39.2	-64.0	-55.1
Sudan	10.3	19.1	16.0	6.8	6.7	7.2	-34.5	-64.8	-54.9
Tanzania	11.8	26.8	33.8	9.4	6.9	10.3	-19.9	-74.3	-69.6
	k=4			k=4			k=4		
Bangladesh	14.4	30.3	23.5	5.9	5.9	6.2	-58.7	-80.6	-73.4
China	16.0	27.0	17.1	5.2	11.2	5.5	-67.5	-58.5	-67.5
Egypt	12.3	23.1	17.8	5.3	6.0	5.8	-56.6	-73.9	-67.4
India	30.8	25.1	40.4	14.0	25.7	35.4	-54.4	2.4	-12.3
Indonesia	14.1	21.9	20.7	6.0	6.8	7.1	-57.3	-69.0	-65.9
Mozambique	12.6	22.2	21.5	6.9	7.9	8.4	-44.9	-64.3	-60.7
Nicaragua	21.5	32.8	27.4	7.0	8.1	7.7	-67.3	-75.3	-71.8
Pakistan	20.9	52.7	35.0	5.9	4.8	5.8	-71.7	-90.9	-83.6
Philippines	12.8	23.6	19.0	6.1	6.6	6.6	-52.6	-71.9	-65.2
Sudan	12.8	18.8	17.4	6.8	6.7	7.2	-46.9	-64.2	-58.5
Tanzania	14.3	24.8	31.8	9.4	6.9	10.3	-34.0	-72.3	-67.6
	k=6			k=6			k=6		
Bangladesh	17.0	40.9	30.9	5.9	5.9	6.2	-65.1	-85.6	-79.8
China	19.7	35.1	21.0	5.2	11.2	5.6	-73.5	-68.0	-73.5
Egypt	14.6	27.6	21.7	5.3	6.0	5.8	-63.4	-78.2	-73.2
India	34.6	33.6	51.7	14.0	25.7	35.4	-59.4	-23.5	-31.4
Indonesia	15.8	26.3	25.0	6.0	6.8	7.1	-62.0	-74.3	-71.7
Mozambique	14.3	24.2	24.3	6.9	7.9	8.4	-51.7	-67.3	-65.3
Nicaragua	24.4	55.0	40.1	7.0	8.1	7.7	-71.2	-85.3	-80.7
Pakistan	27.0	63.2	42.7	5.9	4.8	5.7	-78.1	-92.4	-86.6
Philippines	14.9	24.1	21.0	6.1	6.6	6.6	-59.5	-72.6	-68.5
Sudan	14.8	21.5	20.7	6.8	6.8	7.2	-54.1	-68.4	-65.0
Tanzania	17.5	30.0	38.8	9.4	6.9	10.3	-46.0	-77.0	-73.5

Source: Authors' calculations

Table 7 Unanticipated normalized standard deviations of monthly wheat import bill changes with and without hedging with at the money options

	Unanticipated normalized standard deviation of monthly import bill changes without hedging			Unanticipated normalized standard deviation of monthly import bill changes, when hedged with at the money options only			Percent difference from unhedged		
	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2008-12
	k=2			k=2			k=2		
Bangladesh	10.0	21.1	16.4	7.6	12.7	10.7	-24.5	-40.0	-34.5
China	11.1	20.3	11.9	6.9	13.5	7.4	-37.9	-33.5	-37.9
Egypt	9.4	21.5	15.5	6.4	13.1	10.0	-31.6	-39.3	-35.9
India	24.3	27.7	41.3	20.7	25.5	37.4	-14.9	-7.8	-9.3
Indonesia	10.9	18.7	17.0	7.7	11.6	11.2	-29.3	-37.9	-34.5
Mozambique	9.4	15.0	14.9	8.1	8.1	10.5	-13.3	-45.9	-29.6
Nicaragua	13.8	23.6	18.8	9.5	9.1	9.8	-31.6	-61.3	-47.8
Pakistan	14.9	48.2	30.6	9.0	29.9	19.4	-39.6	-38.0	-36.6
Philippines	10.0	18.4	14.7	7.6	11.6	10.1	-23.2	-36.8	-31.3
Sudan	10.3	19.1	16.0	8.1	12.1	11.0	-21.6	-36.9	-31.4
Tanzania	11.8	26.8	33.8	11.6	17.0	22.7	-2.1	-36.7	-32.9
	k=4			k=4			k=4		
Bangladesh	14.4	30.3	23.5	10.3	15.1	13.4	-28.1	-50.1	-43.1
China	16.0	27.0	17.1	9.1	16.1	9.7	-43.3	-40.2	-43.2
Egypt	12.3	23.1	17.8	8.3	10.9	9.8	-32.2	-52.7	-45.0
India	30.8	25.1	40.4	29.2	26.1	39.6	-5.1	3.9	-2.0
Indonesia	14.1	21.9	20.7	9.7	10.7	11.4	-30.8	-51.3	-45.1
Mozambique	12.6	22.2	21.5	10.4	11.2	12.3	-17.5	-49.4	-42.6
Nicaragua	21.5	32.8	27.4	15.4	10.8	14.5	-28.7	-67.0	-47.3
Pakistan	20.9	52.7	35.0	14.5	30.2	21.7	-30.6	-42.7	-38.1
Philippines	12.8	23.6	19.0	9.1	11.7	10.9	-28.7	-50.4	-42.8
Sudan	12.8	18.8	17.4	9.7	9.1	10.2	-23.6	-51.7	-41.4
Tanzania	14.3	24.8	31.8	12.8	14.8	20.3	-10.4	-40.6	-36.3
	k=6			k=6			k=6		
Bangladesh	17.0	40.9	30.9	12.4	21.1	17.6	-27.5	-48.3	-43.0
China	19.7	35.1	21.0	10.8	21.9	11.5	-45.2	-37.6	-45.0
Egypt	14.6	27.6	21.7	10.0	12.7	11.6	-31.9	-54.0	-46.6
India	34.6	33.6	51.7	29.3	28.2	42.4	-15.2	-16.1	-18.0
Indonesia	15.8	26.3	25.0	10.5	12.3	12.8	-33.2	-53.1	-48.7
Mozambique	14.3	24.2	24.3	11.4	12.1	13.4	-20.5	-49.8	-44.7
Nicaragua	24.4	55.0	40.1	18.6	26.7	22.9	-24.0	-51.6	-42.8
Pakistan	27.0	63.2	42.7	19.8	36.5	27.2	-26.7	-42.2	-36.3
Philippines	14.9	24.1	21.0	10.5	11.4	11.5	-29.9	-52.9	-45.1
Sudan	14.8	21.5	20.7	11.0	8.7	10.9	-25.6	-59.2	-47.3
Tanzania	17.5	30.0	38.8	16.1	16.2	22.5	-7.7	-46.0	-42.0

Source: Authors' calculations

Table 8 Unanticipated normalized standard deviations of monthly maize import bill changes with and without hedging with futures

	Unanticipated normalized standard deviation of monthly import bill changes without hedging			Unanticipated normalized standard deviation of monthly import bill changes, when hedged with futures only			Percent difference from unhedged		
	1985-1 to 2005-12	2006-1 to 2008-12	1985-1 to 2008-12	1985-1 to 2005-12	2006-1 to 2008-12	1985-1 to 2008-12	1985-1 to 2005-12	2006-1 to 2008-12	1985-1 to 2008-12
	k=2			k=2			k=2		
Egypt	11.4	14.4	13.8	5.5	5.0	5.7	-51.8	-64.9	-58.8
Indonesia	16.8	34.1	25.7	7.6	8.6	8.6	-54.4	-74.7	-66.5
Kenya	16.9	26.7	22.9	6.8	6.1	6.9	-59.8	-77.0	-69.9
Malawi	17.3	29.1	19.5	9.3	14.7	10.2	-46.3	-49.6	-47.8
Mozambique	11.2	32.8	15.7	4.6	7.2	5.1	-58.4	-78.2	-67.7
Tanzania	20.3	12.6	19.0	9.5	4.3	8.6	-53.1	-66.1	-54.9
	k=4			k=4			k=4		
Egypt	16.1	20.1	19.8	5.5	5.0	5.7	-66.0	-74.9	-71.3
Indonesia	23.4	26.2	26.0	7.6	8.6	8.6	-67.4	-67.1	-66.9
Kenya	25.7	49.4	40.0	6.8	6.1	6.9	-73.6	-87.6	-82.7
Malawi	29.1	60.0	35.1	9.3	14.6	10.2	-68.1	-75.6	-70.9
Mozambique	16.6	34.8	20.1	4.7	7.2	5.0	-71.9	-79.4	-74.8
Tanzania	23.2	24.9	24.3	9.5	4.3	8.6	-59.2	-82.9	-64.7
	k=6			k=6			k=6		
Egypt	18.1	22.6	23.1	5.5	5.1	5.7	-69.8	-77.7	-75.4
Indonesia	26.8	24.8	27.9	7.6	8.7	8.6	-71.6	-65.1	-69.2
Kenya	35.9	51.6	46.9	6.8	6.1	6.9	-81.1	-88.1	-85.3
Malawi	33.0	65.8	39.5	9.3	14.6	10.2	-71.8	-77.8	-74.2
Mozambique	21.0	35.2	23.9	4.7	7.2	5.1	-77.7	-79.6	-78.8
Tanzania	27.3	40.2	32.6	9.4	4.2	8.6	-65.4	-89.5	-73.7

Source: Authors' calculations

Table 9 Unanticipated normalized standard deviations of monthly maize import bill changes with and without hedging with at the money options

	Unanticipated normalized standard deviation of monthly import bill changes without hedging			Unanticipated normalized standard deviation of monthly import bill changes, when hedged with at the money options only			Percent difference from unhedged		
	1985-1 to 2005-12	2006-1 to 2008-12	1985-1 to 2008-12	1985-1 to 2005-12	2006-1 to 2008-12	1985-1 to 2008-12	1985-1 to 2005-12	2006-1 to 2008-12	1985-1 to 2008-12
	k=2			k=2			k=2		
Egypt	11.4	14.4	13.8	7.9	26.0	20.9	-30.8	81.2	51.0
Indonesia	16.8	34.1	25.7	12.2	13.0	14.0	-27.4	-61.8	-45.4
Kenya	16.9	26.7	22.9	8.9	74.1	53.3	-47.5	177.2	132.8
Malawi	17.3	29.1	19.5	12.7	28.5	15.9	-26.8	-2.1	-18.4
Mozambique	11.2	32.8	15.7	7.9	35.9	15.1	-29.6	9.3	-4.0
Tanzania	20.3	12.6	19.0	14.3	101.2	53.4	-29.6	701.9	181.4
	k=4			k=4			k=4		
Egypt	16.1	20.1	19.8	10.1	45.5	35.4	-36.9	125.7	78.6
Indonesia	23.4	26.2	26.0	15.6	17.1	18.3	-33.4	-34.7	-29.6
Kenya	25.7	49.4	40.0	11.7	73.6	53.4	-54.4	49.0	33.5
Malawi	29.1	60.0	35.1	16.9	115.1	46.6	-42.1	92.0	32.8
Mozambique	16.6	34.8	20.1	10.2	52.6	22.0	-38.4	51.1	9.5
Tanzania	23.2	24.9	24.3	18.7	96.9	53.9	-19.2	289.8	121.7
	k=6			k=6			k=6		
Egypt	18.1	22.6	23.1	10.8	44.1	34.2	-40.3	94.9	48.1
Indonesia	26.8	24.8	27.9	17.0	19.3	20.0	-36.6	-22.1	-28.3
Kenya	35.9	51.6	46.9	17.3	67.6	49.9	-51.7	31.1	6.3
Malawi	33.0	65.8	39.5	19.1	98.8	41.3	-42.1	50.3	4.6
Mozambique	21.0	35.2	23.9	13.4	145.2	55.1	-36.4	312.9	130.7
Tanzania	27.3	40.2	32.6	19.1	61.7	36.0	-30.0	53.2	10.6

Source: Authors’ calculations

Table 10 Differences between unhedged and hedged wheat import bills

	Average monthly import bills without hedging ('000 USD)		Average monthly import bills with futures hedging (percent difference from average unhedged import bills)		Average monthly import bills with at the money options hedging (percent difference from average unhedged import bills)	
	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12
	k=2					
Bangladesh	19001	41690	-0.3	-0.6	-1.4	-1.6
China	80701	3370	-0.7	-0.8	-2.3	-1.3
Egypt	80816	161110	0.0	-0.3	-1.2	-1.9
India	8696	54177	2.7	-5.3	4.5	-5.4
Indonesia	39354	107564	0.3	-1.4	2.1	-2.4
Mozambique	2406	7051	0.5	-3.9	1.5	-3.9
Nicaragua	1254	2512	0.0	-3.2	1.4	-3.5
Pakistan	19523	34622	-1.0	7.6	1.7	1.8
Philippines	25505	54984	0.3	-1.4	2.5	-2.4
Sudan	9230	22000	0.5	-1.1	-0.1	-2.4
Tanzania	1852	10168	1.3	2.4	3.2	-0.1
	k=4					
Bangladesh	19001	41690	0.7	-1.2	-1.9	-4.9
China	80701	3370	-1.0	0.9	-3.2	-4.9
Egypt	80816	161110	0.8	-3.5	-1.6	-7.1
India	8696	54177	3.7	-6.4	5.6	-9.5
Indonesia	39354	107564	1.2	-4.0	2.0	-7.5
Mozambique	2406	7051	1.7	-5.3	1.2	-11.2
Nicaragua	1254	2512	1.6	-4.6	1.9	-7.0
Pakistan	19523	34622	0.5	5.8	2.2	-0.8
Philippines	25505	54984	1.1	-3.3	2.4	-7.8
Sudan	9230	22000	1.6	-5.3	-0.8	-8.9
Tanzania	1852	10168	3.2	0.5	3.2	-4.9
	k=6					
Bangladesh	19001	41690	1.1	-3.5	-2.9	-6.2
China	80701	3370	-1.8	-0.2	-3.9	-3.1
Egypt	80816	161110	1.1	-7.5	-2.2	-10.6
India	8696	54177	2.7	-8.8	9.5	-0.3
Indonesia	39354	107564	1.5	-7.9	1.6	-11.7
Mozambique	2406	7051	2.2	-8.7	-0.4	-7.4
Nicaragua	1254	2512	2.0	-3.3	0.7	-7.8
Pakistan	19523	34622	1.0	2.5	5.6	1.5
Philippines	25505	54984	1.5	-8.1	1.5	-12.0
Sudan	9230	22000	2.2	-9.4	-2.9	-14.6
Tanzania	1852	10168	5.1	-2.7	2.4	-7.0

Source: Authors' calculations

Table 11 Differences between unhedged and hedged maize import bills

	Average monthly import bills without hedging ('000 USD)		Average monthly import bills with futures hedging (percent difference from average unhedged import bills)		Average monthly import bills with at the money options hedging (percent difference from average unhedged import bills)	
	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12	1985-7 to 2005-12	2006-1 to 2008-12
	k=2					
Egypt	25918	59112	0.9	-2.6	5.0	11.6
Indonesia	5677	10316	1.3	-6.2	8.7	-1.1
Kenya	5046	8941	-2.4	-5.2	8.6	20.6
Malawi	4776	4345	-4.7	-14.3	-3.5	-7.3
Mozambique	1986	2013	1.2	1.3	3.1	9.9
Tanzania	556	835	2.0	-3.0	0.1	23.0
	k=4					
Egypt	25918	59112	2.3	-6.2	6.3	12.2
Indonesia	5677	10316	2.3	-5.4	9.7	2.4
Kenya	5046	8941	-1.6	-10.7	8.4	12.5
Malawi	4776	4345	-3.0	-10.1	-2.2	9.6
Mozambique	1986	2013	2.9	-5.4	4.1	10.0
Tanzania	556	835	3.4	-7.7	1.8	25.6
	k=6					
Egypt	25918	59112	3.2	-10.6	7.4	5.6
Indonesia	5677	10316	3.3	-6.9	11.1	0.2
Kenya	5046	8941	0.2	-17.6	9.1	3.8
Malawi	4776	4345	-3.4	-18.9	-1.3	1.7
Mozambique	1986	2013	4.7	-11.2	5.6	32.0
Tanzania	556	835	4.9	-16.3	2.6	-6.9

Source: Authors' calculations