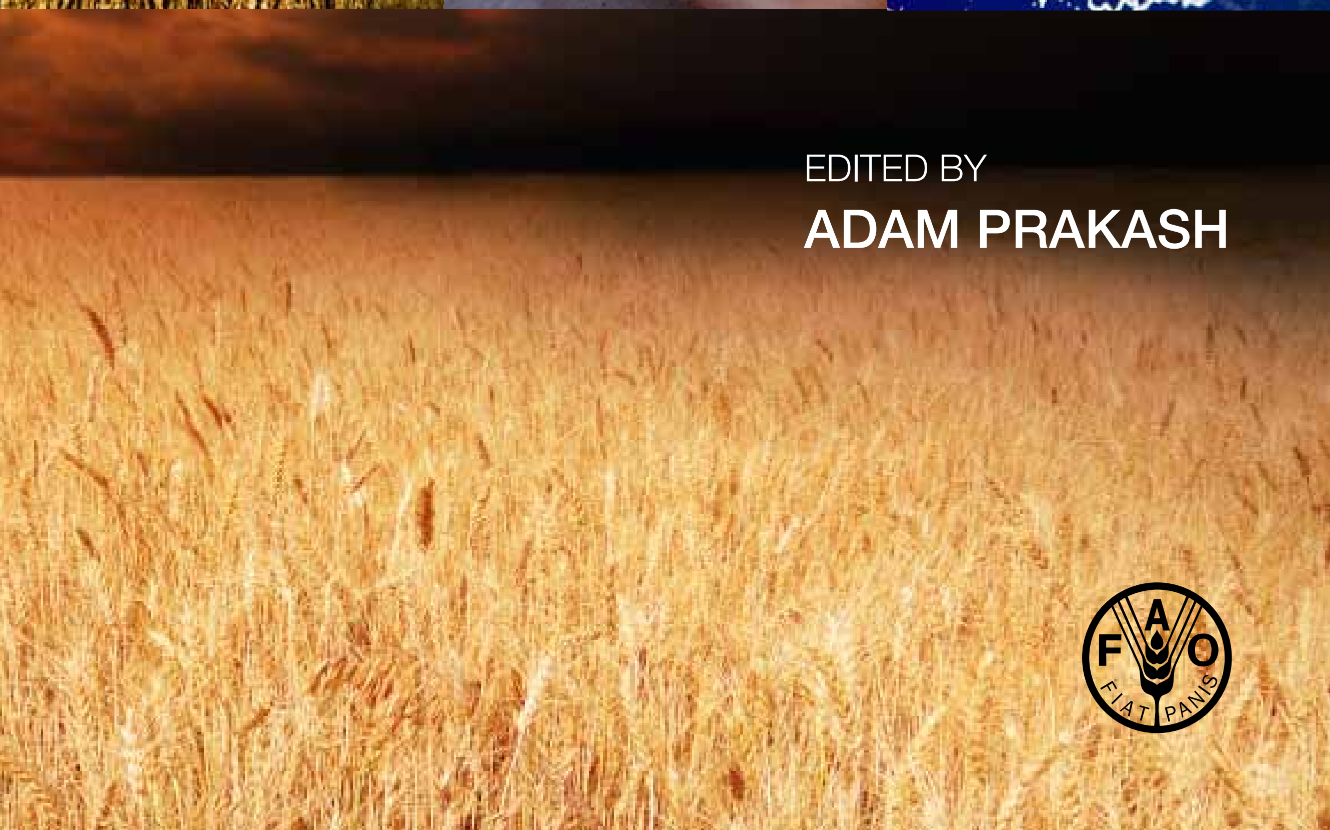
SAFEGUARDING FOOD SECURITY IN VOLATILE GLOBAL MARKETS





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Safeguarding food security in volatile global markets

Edited by Adam Prakash

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Chapter 19

Using futures and options to manage price volatility in food imports: theory[1]

Alexander Sarris, Piero Conforti and Adam Prakash[2]

An important long-term development in world agricultural trade has been the shift - some two decades ago - of developing countries from being net exporters to a position of being net importers. Among developing countries, those classified as Least Developed Countries (LDCs) and Low-Income Food-Deficit Countries (LIFDCs) have witnessed a rapid worsening of their agricultural trade balance in the last fifteen years. The high price episode of 2006-08 brought this problem to the fore, in which the basic food import bills of LIFDCs increased by over 40 percent between 2007 and 2008, to USD 152 billion; and in 2010 imported food costs are expected to rise to a record USD 164 billion (FAO, 2010).

Analysis by Gurkan et al. (2003) indicated that the need to import food was an important determinant of economic stress in LDCs between the mid-1980s and 1990s. Their study showed that the growth in these countries' food import bills consistently outstripped that of GDP, as well as total merchandise exports. Changes in import unit costs of many important food commodities accounted for roughly two-thirds of the variation in food import bills. That same study also revealed that LDCs faced large and unanticipated price "spikes" that exacerbated their already precarious food security situation. Coupled with substantial declines in food aid over the same period, these developments have brought about a significant increase in the vulnerability of developing countries.

In light of the above developments, it seems that the issue of managing the risks of food imports has increased in importance, and is a major issue for several LIFDCs. The major problem is not price or quantity variations *per se*, but rather unforeseen and undesirable departures from expectations on food import needs, such as those that affected many countries during the 2006-08 period.

During this period, the combined increase of basic food prices, such as of 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 most deeply affected (Demeke et al., 2011; FAO, 2008). In addition, given the simultaneous dependence of many of these countries on commodities both in importing and exporting, and with commodity prices tending not to move together, the likelihood of high import prices, coupled with low export prices is a real concern and presents new challenges for policy-makers. It thus becomes imperative to explore possible national strategies to deal with food import risks.

1 This chapter is based on several working papers which precede Sarris et. al. (2011).

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A recent review of policy options (Byerlee et al., 2006) highlighted the difficulties 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 of using innovative organized market-based instruments. Indeed the proliferation of international risk management instruments, such as futures and options for basic food commodities, may present opportunities for managing the risks that LIFDCs face.

The purpose of this chapter is to explore a potentially successful way in which vulnerable countries can manage some of these risks, in particular those arising from unpredictable behaviour of import prices for staple food commodities. We consider wheat imports of several of the major LIFDCs, and examine, within a counterfactual scenario, the benefits or losses that would have been incurred had they combined their cash imports with simple and transparent hedging strategies based on futures and options. The assessment is made in terms of changes in the variance of unpredictable foreign exchange costs for cereal imports, over a past period of time which includes the 2006-08 high price episode.

Background

There is scant literature on the use of risk management tools to hedge against import instability. 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, which 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) explored only one particular hedging rule. A volume edited by Claessens & (eds.) 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 in maize imports.

Food imports take place under a variety of institutional arrangements in developing countries. A study on the structure of food trade in developing countries (Gurkan et al., 2003) notes that while in some LIFDCs state institutions still play a very important role in the export of basic foods, food imports have been mostly privatized in recent years. State agencies mostly 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 others relevant to domestic welfare. Once 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 result in domestic social problems and food insecurity. The third problem of such an agent is how to minimize the overall cost of fulfilling import requirements, given uncertainties in international prices and international freight rates, and to manage the risks of unanticipated cost overruns. Finally, but not least, the agent must finance the transaction, either through own resources, or some financing mechanisms.

The problems of private import agents are not much different from those 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. As far as unpredictability of domestic production, international prices and domestic demand are concerned, the private importer faces risks similar to those of the public agent. Moreover s(he) faces an additional 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 spike of 2006-08, surveys documented the adoption of many short-term policies in response to high global prices of staple foods, which created considerable additional risks for private agents (Demeke et al., 2011). Furthermore, the private agent may be more credit and finance-constrained than the public agent. In fact the study by Gurkan et al. (2003) indicated that the most important problem of private traders in LIFDCs is the availability of import trade finance.

Given the focus of this chapter on hedging strategies, we will not be concerned with the particular institutional character of the agent that imports. Rather, we will refer to an "agent" as the institution, public or private, that does both the actual importing as well as the hedging without specifying the institutional arrangements in the importing country. The assumption is that such an agent will need to plan for imports, in physical or financial terms, ahead of the actual time when imports need to be ordered.

Under the institutional arrangements currently in place in most countries, it is unrealistic to imagine that one single agent would manage 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 there will be no agent that imports a fixed share of the total amount for any country unless there is a monopoly on imports, the fixed share assumption is adopted both because the market information requirements and actions of both private and public agents are the same, and because data for the empirical *ex post* simulations are available only for 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.

Theoretical framework

Consider again the above mentioned agent who needs to plan imports of some basic food for a LIFDC. The present analysis focuses on wheat, which is a widely traded cereal,[3] characterized by well established cash, futures and options markets, and is imported by many LIFDCs[4]. The problem posed is the following: In the course of a year, the agent will need to import certain amounts of wheat for delivery to the country's border in a given month. We shall assume that in any given month the agent has imperfect information on the amounts to be imported several months ahead. In most countries total import requirements will be broadly known some time in advance by traders and other market participants, as domestic production conditions normally become clear several months before the onset of marketing. However, we consider the case in which future import requirements are uncertain.

3 The analysis is extended to maize in Sarris et al. (2011).

4 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. While some short-term substitution may take place between the various foods imported - an issue on which we have no information - we will examine wheat imports only and separately, assuming implicitly that hedging would not affect the short-term import demand of wheat. Exploring the possibility that risk management affects the volumes of food imports is beyond the objectives of this chapter.

In order to simplify 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, s(he) will need to import m_1^e units of wheat. The superscript e denotes that this amount is the current expectation of import needs at time 1, conditioned on information available at time 0. The price the agent will pay when ordering m_1^e at time 1 will be denoted as p_1. Define the following variables:

1. f_0 is the futures price of the commodity observed in a relevant organized commodity market in the current period (denoted by a subscript 0) for the futures contract expiring at, or nearest after, period 1, at which the actual order for imports is placed;
2. f_1 is the price of the same futures contract at time 1;
3. x is the amount of futures contracts (in units of the quantity of the commodity) purchased at the current period;
4. z is the amount of call options contracts purchased also at the current period. The call option contract is written on the same underlying futures contract expiring at or soonest after period 1, and stipulates that if the futures price f_1 at time 1 is higher than 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.
5. 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 the difference $f_1 - s$ 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:

$$M_1 = p_1 m_1 - (f_1 - f_0)x - (\pi_1 - r_0)z = p_1(m_1^e + \mu_1) - (f_1 - f_0)x - (\pi_1 - r_0)z \tag{1}$$

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. This is written as

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

where the second identity above defines the notation for the conditional variance[5]. The first order conditions for this problem can be written as follows[6]:

$$E\left\{\frac{\partial Var_0[M_1]}{\partial x}(f_1 - f_0)\right\} = 0 \tag{3}$$

$$E\left\{\frac{\partial Var_0[M_1]}{\partial z}(\pi_1 - r_0)\right\} = 0 \tag{4}$$

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 nearest futures price

$$p_1 = \alpha + \beta f_1 + \theta_1 \tag{5}$$

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

5 In principle, it would be possible to consider a more general concave utility function $u(.)$ over M; but this would complicate matters without adding much to the argument. Our objective in this chapter is to discuss how to reduce the unpredictability of imports; choosing the variance helps focus the argument on the existence of benefits from hedging, rather than on the shape of the utility function, which was the object of several other contributions, such as Benninga et al. (1984) and Lence & Hayes (1994). Analyses using more general utility functions include Lapan et al. (1991) and Sakong et al. (1993).

6 The second order conditions hold because of the convexity of M.

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 is the expected value of π_1. Finally, it is assumed for the time being that the eventual adjustment to imports μ_1 is only a function of domestic revisions to requirements, owing to improved domestic information, and is not correlated with p_1, which is the prevailing international price at time 1. In principle, this is not entirely correct, as at time 1, when the order is placed, world prices may call for additional adjustment of planned imports. For instance, prices may be high enough to require a reduction regardless of the conditions prevailing in the domestic market. Such adjustments are usually the consequence of financial constraints or considerations; they 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 ignored for the time being. 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).

It could be hypothesized 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 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;

$$z = \beta m_1^e \frac{Cov(f_1, \pi_1)}{Var(\pi_1)} \tag{6}$$

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 (6) is equal to the variance ofπ_1. Hence the coefficient that multiplies the optimal futures-only hedge ratio, βm_1^e, above is equal to 1. 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 these results do not depend on the fact that the *ex post* imports m_1 is stochastic, as the welfare criterion is equal to the variance of M_1. If the welfare criterion was a concave utility of M_1, then the resulting optimal policy would be a combination of futures and options (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 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, as these deviations are the most detrimental from a food security standpoint 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. Given the assumptions made about the efficiency of the futures and options markets, and if it is assumed that the truncation level is the mean of the underlying distribution of imports, it can be shown using the formulas in Greene (2000) that both the truncated mean and the truncated variance of M_1 are functions only of the conditional variance of M_1. Hence, if the assumed objective of the agent is to minimize the truncated mean of the import bill deviations, it can be shown that this objective corresponds to the minimization of the variance of M_1. The same point holds 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. To simplify the discussion, assume a simple form of linear *ex post* import adjustment as follows.

$$m_1 = m_1^e - e\left(p_1 - p_1^e\right) + \mu_1 \tag{7}$$

Compared with the simpler formula for the import rule indicated in (6), this incorporates adjustments following from 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.

$$x = \beta\left(m_1^e - ep_1^e\right) - e\beta^2 \frac{A-B}{Var f_1 - Cov\left(f_1, \pi_1\right)} \tag{8}$$

$$z = -e\beta^2 \frac{-ACov(f_1, \pi_1) + BVar f_1}{Var\pi_1\left[Var f_1 - Cov\left(f_1, \pi_1\right)\right]} \tag{9}$$

where

$$A = E_0(f_1 - f_0)^3 \tag{10}$$

$$B = E_0\left[(f_1 - f_0)^2(\pi_1 - r_0)\right] \tag{11}$$

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 (8) and (9) 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 indicates that even with the simple variance criterion, the optimal hedge can involve a combination of futures and options. Earlier research concluded that a mixed hedging strategy was optimal under two conditions, namely when there is uncertainty in the *ex post* imports; and when the objective function involves a concave utility (Sakong et al., 1993). We have shown that a combined rule is also optimal when there are budget constraints that may imply *ex post* adjustments. Such conditions are relevant in LIFDCs that face constraints in the availability of foreign exchange. In practice, however, it is very difficult, if not impossible to estimate the *ex post* adjustment parameters e: even for a monopolistic import agent, it is difficult to obtain information on *ex ante* and *ex post* import transactions. Hence in the *ex post* simulations described below in the chapter we will assume that e is equal to zero.

Another possibility is for the importer to buy at time t, k months ahead of when delivery is required, 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, s(he) will incur storage cost, and deal with price

Table 19.1: Wheat import profiles of selected LIFDCs (000 tonnes)

	Average imports	% Share in LIFDC imports	% Share in world imports	% Share in consumption		Average cereal imports	% Share in cereal imports
	1980–08	1980–08	1980–08	1980–90	1991–08	1980–08	1980–08
Bangladesh	1 622	3.9	1.6	59.5	57.7	2 285	71
China, Mainland	6 772	16.3	6.6	12.5	3.7	8 813	76.8
Egypt	6 839	16.4	6.7	73.2	53.2	9 756	70.1
India	1 122	2.7	1.1	2.5	1.7	1 359	82.6
Indonesia	3 137	7.5	3.1	101.2	103.7	4 844	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	1 345	3.2	1.3	6.3	8.5	1 368	98.3
Philippines	1 956	4.7	1.9	103.4	100.2	2 963	66
Sudan	772	1.9	0.8	70.3	68.4	960	80.4
Tanzania, Un. Rep.	177	0.4	0.2	44.8	85.4	370	47.9
Total of Above	24 049	57.8	23.4	33 527			
Total LIFDC	41 638	100	40.5	62 846			
World	102 786	220 716					

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 (periods t and $t+k$ in our discussion), albeit this cost can be negative because of backwardation[7]. Hence buying futures can be considered as an alternative to inventory holding, albeit the market-determined cost of storage in Chicago may have little to do with the cost of storage - and any implicit backwardation - in local markets. 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, 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, there is no information available on this issue, and we do not pursue it further in this chapter.

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 information at this frequency over a reasonably long time span. Out of the LIFDCs group, we selected eleven countries that have engaged in large wheat imports over the past 25 years (Table 19.1).

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. It is worth noting

7 See Considine and Larson (2001) on risk premiums and backwardation.

the high share of wheat in the countries' total cereal imports, the percentages reported in the last column, indicate that wheat is the most important cereal imported. Moreover, with the exception of large countries like China (Mainland), India and Pakistan, wheat imports account for a large share of the total wheat consumed domestically.

Different profiles of countries imply different problems associated with cereal imports. For example, large countries could experience deficits and surpluses in different areas, and this may prompt 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 behaviour is observed in some of the countries included in our sample. Occasionally, importing countries may face conditions that would make regular hedging strategies 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 with the variance of the basis between the international purchasing centre and their import point. These caveats should be kept in mind when interpreting the results.

Most of the actual wheat 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 United States of America, Australia and Argentina. Sarris et al. (2006) showed, however, that export prices in these markets are strongly correlated, and also that the import unit values of the selected importing countries are significantly correlated 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 as a proxy for the import price (minus transport cost) of the importing country. We chose US Gulf prices to represent international reference prices for imports of wheat. Similarly we consider the Chicago Mercantile Exchange (CME) as the major hedging market for orders made with reference to the Gulf prices.

Consider first the problem of hedging the price risk for an amount of wheat equal to the hedge ratio times the known amount that will be imported some months ahead. As shown, *ex post* uncertainty about the level of imports does not affect 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 analysed here imply transactions through futures or options. In terms of data, we employed firstly the actual imports of wheat for all LIFDCs on an annual basis (both calendar year as well as July-June) from the 1960s. Secondly, we used International Wheat Council (IWC) and FAO data on monthly wheat imports for LIFDCs by origin of imports, since 1995. Given this monthly information, for the years in which monthly import data are not available we assumed that the monthly import pattern is the same as the average pattern of the years for which monthly observations are available. Thirdly, futures and options daily data were obtained from the CME 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 undertaken 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 contracting, and selling them later, namely when the actual physical transaction for wheat 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 grains 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 price at which wheat imports will be valued and eventually paid are those of one month ahead of the actual physical arrivals at the border.

The hedging rules are defined by the following parameters:

1. the day of the year at which the contract (futures or option) is bought;
2. the contract to be purchased (namely the month for which a futures or option contract is purchased);
3. the amount to be purchased under the contract;
4. for options, the strike price at which the call option is purchased.

We will simulate the following two sets 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 s(he) needs to contract the actual delivery. The contract date is assumed to be one month before the needed 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 requirements, the importing agent needs to physically import 100 000 tonnes of wheat in December. 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 is the November price. Therefore, 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 totalling $\beta \times 100\,000$ tonnes in July (namely in the $11 - 4 = 7^{\text{th}}$ 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 above example, the actual forecasted transaction is in November, and the nearest traded futures is the December contract, 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 s(he) needs to hedge. This is an approximation, as the actual futures contracts are available only for fixed lump amounts (for instance the standard CME wheat futures contract is for 5 000 bushels[8] or about 130 tonnes), 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 determined, for the simulations we still need an assumption on the exact days at which the agent will purchase and, later, sell the contracts; this was assumed to be the closest day to the middle of the month[9]. The same strategy is applied month after month. Concerning costs, it was assumed that buying or selling futures implies a USD 0.15 per tonne commission, as in Faruqee et al. (1997); and that each futures transaction requires a deposit margin equivalent of 5 percent of its value. We also assumed that there is an opportunity cost on this margin, valued at a rate equal to the United States of America base interest rate, which changes every month (published by the United States of America Federal Reserve). This cost is calculated over the period of the hedge.

8 In the CME one could purchase also mini-wheat and mini-corn contract which trade in 1 000 bushel units.

9 The sensitivity of results to this assumption was checked by repeating the simulations under the assumption that transactions would take place at the beginning and at the end of the month. The results were virtually unchanged; hence we decided to report only those for the mid-month transactions.

Rule 2. Hedging with options 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 also the strike price has to be determined. The strike price is parameterized as $(1+\alpha)p^f_{t,t+k}$, 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 $p^f_{t,t+k}$ for which insurance is sought. Hence if $\alpha = 0.1$, the (out-of-the-money) call option bought implies that if the future price observed at the time of ordering is above the strike price - which as per the option specification is 1.1 times the future price observed at the time of purchase of the option - 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 in the seventh month of the year, namely 15 July, the agent purchases a call option with $\alpha = 0.1$ and $k = 4$. This means that the call option expires in November (month 7+4), when the contract will have be made for the physical wheat shipment to be delivered in December. Suppose that on 15 July, the December future is quoted at USD 90.9 per tonne[10]. With $\alpha = 0.1$ the desired strike price at which the call option will be bought is P_s = USD 100 = (1.1×90.9). 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 USD 100 among those quoted. Assume that this is USD 98.0 and that the cost of buying this call is PR= USD 12.0. The calculation of the gain from the option purchase examines the December future price in mid-November; as mentioned we consider the settlement price on 15 November or the nearest trading day. Suppose that this price has moved upward beyond expectations, to P_{NF} = USD 120. In this case the option will be exercised, and the net gain, taking into account the transactions cost, will be $N = (120-98)-12-0.045\times 12$ =USD 9.46. Suppose now that price growth expectations have not fully materialized, so that the December future on 15 November has only reached $P_{NF} = 95$. In this case the option will not be exercised, and the net loss accounted for will be $N = -12-0.045\times 12$ = USD -12.54.

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 presented 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

$$M_{t+k} - E(M_{t+k,t}) = \left\{p_{t+k}m_{t+k} - E(p_{t+k,t})m^e_{t+k}\right\} \tag{12}$$

and then compute the variance (or standard deviation) of the changes in (12) over a given historical period. When the same imports are hedged with futures, the unpredictable change in the import cost is equal to:

$$M_{t+k} - E(M_{t+k,t}) = \left[p_{t+k}m_{t+k} - E(p_{t+k,t})m^e_{t+k}\right] - \beta\left(f_{t+k} - f_t - \tau_f f_t - g_{t,t+k} f_t\right)m^e_{t+k} \tag{13}$$

where τ_f denotes the unit transactions cost of buying a futures contract, g is the margin requirement (assumed to be 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

[10] Prices are actually quoted in cents per bushel, but we refer to dollars per tonnes for simplicity.

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. In the simulations we ignore this aspect of futures hedging, albeit for cash constrained LIFDCs it may be important.

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

$$M_{t+k} - E(M_{t+k,t}) = \left[p_{t+k}m_{t+k} - E(p_{t+k,t})m^e_{t+k}\right] - \beta(\pi_{t+k} - r_t - \tau_o r_t)m^e_{t+k} \tag{14}$$

where π_{t+k} is the actual realized profit on the option contract (namely equal to $f_{t+k} - s$, if this quantity is positive at time $t+k$, and zero otherwise); and τ_o denotes the unit transactions cost of buying a call option contract. As discussed earlier, the *ex ante* uncertainty about the value of the eventual physical 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 (12)-(14) we need to estimate the conditional expectation of the future cash price. Under the assumption (5), 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 futures 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 (12)-(14):

$$E(p_{t+k,k}) = \alpha + \beta f_t^{t+k} \tag{15}$$

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.

The simulation exercise compares the standard deviations of the normalized expressions in (12)-(14). The normalization is obtained by dividing the expression in (12)-(14) 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 difference is estimated in the variability measures of the above expressions are owing 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 import bills for grains. As discussed above, they are computed on the assumption that the price paid by a country when importing from the United States of America or any of the other main exporters is the Gulf price.[11]

Before undertaking the simulations, we analysed whether the CME futures prices can be employed as expectations of the reference cash prices, as per equation (15); and verifies that

[11] This is an approximation, as there may be significant transport and other country specific transactions related cost differentials between the Gulf prices and the border prices in the country. But as data on actual transactions and monthly c.i.f. prices are unavailable, it is meant to provide at least some indicative figure. 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 world prices. However, this may not be the case in periods of price spikes, depending on the source of the spike. In point of fact, during the recent price boom of 2007-08, 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.

CME futures prices - and hence those of the related options - are indeed effective reference prices for hedging grains imports of the selected LIFDCs.

The bulk of wheat imports into the countries included in our sample is obtained from the United States of America, Australia and Argentina. Hence we considered the 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[12]. Time series analysis involving co-integration tests, between the three world wheat reference prices revealed that they move closely together Sarris et al. (2006). Hence we could safely choose one of the three world wheat reference price as the single representative price for wheat imports, and we choose the US Gulf price.

Moreover, we studied the relationship between the Gulf prices and CME spot prices in order to compute hedge ratios and to determine the functional form for price expectations. As futures are defined only for certain months, the CME price that was considered as the corresponding reference futures price for the Gulf market was assumed to be the one for the nearest futures contract.

In order to study the basis risk of the Gulf prices, time series price relations were analysed econometrically. These results indicate that there is a near perfect transmission of long-run price signals between the Chicago futures market and the average Gulf import prices relevant for the selected countries; and this allows hypothesizing that the Chicago futures market is viable to hedge import price risks. However, in the short-run, the relationship between reference export prices and CME prices may not be perfect.

The definition of an optimal hedging dynamic strategy based on the dynamic relation between the country-level import price and the CME prices is beyond the scope of this chapter. As, however, the steady-state relationship in (5) is econometrically robust, deviations in the optimal strategy from one based on the long-run relationship are expected to be small. Moreover, if the unanticipated price variance is reduced by hedging with the static rules simulated in this chapter - as the empirical results show - then it is to be expected that more complex rules will reduce it even further. Thus, in the simulations described below, the assumption is made that the value of the hedging parameter β in equation (15) is equal to the value of the long-run transmission parameter.

Results of hedging strategies with futures and options

Statistics of the measures in (12)-(14) are presented firstly with reference to one unit of imports, in order to show separately the contributions of prices to the overall unpredictability of the import bills. Table 19.2 exhibits the relevant statistics in the form of standard deviations of the relevant percent changes.

Hedging with futures reduces considerably the unexpected variability of import prices for grains, and for all periods simulated. The reductions are substantial, and as large as 72 percent in the 2006-08 period. Standard deviations of futures hedging (the middle set of rows) are homogeneous across the different values of k, as the hedge ratio β is close to one, as seen in Table 19.2. Hence, as per formula (15), the expression (13) reduces largely to the difference between the cash and futures price at time t, whose size is not significantly affected by changes in the *ex ante* futures price which varies with k.

Concerning import bills, Table 19.3 indicates the unanticipated normalized standard deviations of monthly wheat import bill changes with and without hedging with futures only,

[12] Data for these three prices are reported in the IMF International Financial Statistics.

Table 19.2: Average unanticipated prediction errors, coefficients of variation and standard deviations of percentage prediction errors of cash and futures prices for wheat on CME over 1985-2008

		1985-7: 2005-12	2006-1: 2008-12	1985-7: 2008-12
Gulf Price (USD/mt)		143.3	257.6	157.6
$(P_t-E_{t-k}(P_t)/P_t)$ (percent)	k=2	-1.1	1.5	-0.7
	k=4	-1.2	1.6	-0.9
	k=6	-1	4.2	-0.3
$[(F_t-F_{t-k})/P_t]$ (percent)	k=2	-0.3	0.9	-0.2
	k=4	-1.3	1	-1
	k=6	-1.9	3.5	-1.2
CV of Gulf price (percent)		18.9	30.3	33.7
CV of CBOT near futures price		17.1	32.2	31.8
Stdev of $[(P_t-E_{t-k}(P_t))/P_t]$ (percent)	k=2	8.3	16.1	9.6
	k=4	10.9	22.6	13
	k=6	13.3	26	15.6
Stdev of $[(F_t-F_{t-k})/P_t]$ (percent)	k=2	8	16.2	9.4
	k=4	10.4	22.6	12.6
	k=6	12.9	25.6	15.2

for the same periods indicated in the previous table. Table 19.4 reports the same variables for hedging strategies exclusively based on at the money call options.

Several observations are in order. First the ability of a simple linear formula such (15) to predict the subsequent actual cash price performs well on average in "normal periods, even some months in advance. Notice that the average percent forecast errors during the period 1985 to 2005 for all values of were smaller than 1.2 percent. During a period of high prices, namely the episode of 2006-8, the ability of (15) to predict the eventual cash price of wheat deteriorated only slightly for $k=2$ and $k=4$, but more so for $k=6$. This performance is mirrored in the ability of the futures price to forecast the subsequent futures price. The forecast statistics for average unpredictability of the futures prices are quite similar to those of the cash market statistics.

Turning to the variability of *ex ante* predictions, the last two sets of rows in Table 19.2 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 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 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 deviations increase to 10-11 percent, while for $k = 6$ the numbers jump to about 13 percent. Notice, however, that during the food price increase period of 2006-08, 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.

Turning to the unpredictability of the import bills, out of the LIFDCs group, eleven countries were selected that have been wheat importers over the past 25 years, based on availability of monthly import data. 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.

Table 19.3 indicates the unanticipated normalized standard deviations of monthly wheat import bill changes (based on (12)) with and without hedging with futures. Table 19.4 repeats the exercise when hedging is done only with at the money options. The results cover as in the previous tables two periods, namely the period July 1985 to December 2005, namely before the grains price spike, the spike period January 2006 to December 2008 and the two periods combined.

The results in Table 19.3 indicate that for all the countries analysed 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 owing to the behaviour of the cash or futures prices, as these affect all countries in the same fashion. The phenomenon may be owing to the particular pattern of imports of India during the high price period. In fact wheat imports of India during 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. The reductions in unpredictability of import bills seem to be larger during the high price period of 2006-08 compared with the earlier period for all countries and values of k, with the notable exceptions of China (Mainland) and India.

Table 19.4 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 high price 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 period of price turmoil for all countries except China (Mainland) and India.

Concluding remarks and implications for import strategies

The simulated reductions in unpredictability are quite substantial. An important result is that reductions in unpredictability were quite significant during the recent high price period and larger than in normal times. This suggests that during periods of high prices and volatility, 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 CME 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.

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 imports, one may question whether their involvement in the CME would 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 make up 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, as noted in Sarris et al. (2011) these rules will reduce neither the risks involved in variable transactions costs, or transport costs, nor the risks involved in foreign exchange. Some of these risks may be substantial in developing countries, and as 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 part of the basis risk, which may be large for some countries, through organized regional exchanges. This may be possible in some of the countries included in our sample, such as India, China (Mainland) and South Africa. However, it is not clear that such exchanges offer good hedging media for imports to be purchased internationally. These issues call for more extensive research that might involve additional products and markets.

The implications for development policy are that many LIFDCs 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 chapter. There are important benefits from increased predictability especially in securing food supplies, 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 19.3: Unanticipated normalized standard deviations of monthly wheat import bill changes with and without hedging with futures and 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: 2005-12	2006-1: 2008-12	1985-7: 2008-12	1985-7: 2005-12	2006-1: 2008-12	1985-7: 2008-12	1985-7: 2005-12	2006-1: 2008-12	1985-7: 2008-12
	2 = k			2 = k			2 = k		
Bangladesh	10	21.1	16.4	6	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	5.8	-43.1	-72	-62.6
India	24.3	27.7	41.3	14	25.7	35.4	-42.3	-7.2	-14.4
Indonesia	10.9	18.7	17	6.8	6.8	7.1	-37.8	-63.8	-58.5
Mozambique	9.4	15	14.9	6.9	7.9	8.4	-26.1	-47.2	-43.4
Nicaragua	13.8	23.6	18.8	7	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	-81.2
Philippines	10	18.4	14.7	6.1	6.6	6.6	-39.2	-64.8	-54.9
Sudan	10.3	19.1	16	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
	4 = k			4 = k			4 = k		
Bangladesh	14.4	30.3	23.5	5.9	5.9	6.2	-58.7	-80.6	-73.4
China	16	27	17.1	5.2	11.2	5.5	-67.5	-58.5	-67.5
Egypt	12.3	23.1	17.8	5.3	6	5.8	-56.6	-73.9	-67.4
India	30.8	25.1	40.4	14	25.7	35.4	-54.4	2.4	-12.3
Indonesia	14.1	21.9	20.7	6	6.8	7.1	-57.3	-69	-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	8.1	7.7	-67.3	-75.3	-71.8
Pakistan	20.9	52.7	35	5.9	4.8	5.8	-71.7	-90.9	-83.6
Philippines	12.8	23.6	19	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	-72.3	-67.6
	6 = k			6 = k			6 = k		
Bangladesh	17	40.9	30.9	5.9	5.9	6.2	-65.1	-85.6	-79.8
China	19.7	35.1	21	5.2	11.2	5.6	-73.5	-68	-73.5
Egypt	14.6	27.6	21.7	5.3	6	5.8	-63.4	-78.2	-73.2
India	34.6	33.6	51.7	14	25.7	35.4	-59.4	-23.5	-31.4
Indonesia	15.8	26.3	25	6	6.8	7.1	-62	-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	40.1	7	8.1	7.7	-71.2	-85.3	-80.7
Pakistan	27	63.2	42.7	5.9	4.8	5.7	-78.1	-92.4	-86.6
Philippines	14.9	24.1	21	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
Tanzania	17.5	30	38.8	9.4	6.9	10.3	-46	-77	-73.5

Table 19.4: Unanticipated normalized standard deviations of monthly wheat import bill changes with at the money options hedging only

	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:	2006-1:	1985-7:	1985-7:	2006-1:	1985-7:	1985-7:	2006-1:	1985-7:
	2005-12	2008-12	2008-12	2005-12	2008-12	2008-12	2005-12	2008-12	2008-12
		2 = k			2 = k			2 = k	
Bangladesh	10	21.1	16.4	7.6	12.7	10.7	-24.5	-40	-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	-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	7.7	11.6	11.2	-29.3	-37.9	-34.5
Mozambique	9.4	15	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	29.9	19.4	-39.6	-38	-36.6
Philippines	10	18.4	14.7	7.6	11.6	10.1	-23.2	-36.8	-31.3
Sudan	10.3	19.1	16	8.1	12.1	11	-21.6	-36.9	-31.4
Tanzania	11.8	26.8	33.8	11.6	17	22.7	-2.1	-36.7	-32.9
		4 = k			4 = k			4 = k	
Bangladesh	14.4	30.3	23.5	10.3	15.1	13.4	-28.1	-50.1	-43.1
China	16	27	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
India	30.8	25.1	40.4	29.2	26.1	39.6	-5.1	3.9	-2
Indonesia	14.1	21.9	20.7	9.7	10.7	11.4	-30.8	-51.3	-45
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	-47.3
Pakistan	20.9	52.7	35	14.5	30.2	21.7	-30.6	-42.7	-38.1
Philippines	12.8	23.6	19	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
		6 = k			6 = k			6 = k	
Bangladesh	17	40.9	30.9	12.4	21.1	17.6	-27.5	-48.3	-43
China	19.7	35.1	21	10.8	21.9	11.5	-45.2	-37.6	-45
Egypt	14.6	27.6	21.7	10	12.7	11.6	-31.9	-54	-46.6
India	34.6	33.6	51.7	29.3	28.2	42.4	-15.2	-16.1	-18
Indonesia	15.8	26.3	25	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	40.1	18.6	26.7	22.9	-24	-51.6	-42.8
Pakistan	27	63.2	42.7	19.8	36.5	27.2	-26.7	-42.2	-36.3
Philippines	14.9	24.1	21	10.5	11.4	11.5	-29.9	-52.9	-45.1
Sudan	14.8	21.5	20.7	11	8.7	10.9	-25.6	-59.2	-47.3
Tanzania	17.5	30	38.8	16.1	16.2	22.5	-7.7	-46	-42