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Abstract:

The role played by "speculators" during the 2007/08 food price spike is lively disputed. Our analysis focuses on the increasing participation of index funds in agricultural commodity futures markets before the food price spike. Our central theme is to determine if their pre-spike massive entry does prepare the subsequent crisis by maintaining low stock levels. We develop a theoretical model explaining the behaviour of speculators and traders on futures and cash markets. We allow index funds to inflict an informational externality on commercial traders that is supposed to induce a lower desire to hold stock. We find out that, once the production decisions of commercial traders are taken into account into the model, the increased net long position of index funds is inconsistent with lower stocks. We therefore conclude that commodity index funds are not a systematic cause of high market swings and that other relevant causes should be further studied.

Key words: Futures markets, commodity price, index funds, stocks.

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Introduction

The world prices of some agricultural products dramatically increased from 2006 to 2008 and decreased from 2008 to 2010 (figure 1). Many economic analyses have been initiated to understand these unexpected price spikes.[2] These analyses agree that a complex set of interrelated factors explain these price changes. On the other hand, the individual contributions of these factors are highly disputed. Probably most controversial is the role played during the food crisis by the swap dealers hedging the net position of commodity index funds on futures markets[3]. Proponents of the speculative bubble theory mostly rely on statistical correlations to justify their claim. To the contrary opponents to this theory mainly argue that i) the power of these statistical results is rather poor and indeed may suffer from an omitted variable bias, ii) the levels of non commercial open interest were relatively stable during this period, iii) the procedures by which they roll over their long positions are well predictable and thus they are unable to push prices away from fundamental values due to the arbitrage by commercial traders iv) many commodities for which futures markets are either negligible or non-existent also saw significant price increases, v) stock levels were falling rather than increasing.

Our objective in this paper is to contribute to this vast literature on the causes of the commodity prices spike by focusing on the possible role played by index funds before market prices start culminating. Available data from CFTC Commitment of Traders reports show that index funds almost quadrupled their net long speculative position on the Chicago Mercantile Exchange (CME) wheat and corn futures contracts over the period 2004-2006 while their positions slightly fell over the period 2006-2008 (figure 2). Thus the peak level of index holding pre-dates the food price spike. This former rapid and massive involvement of index funds in agricultural futures markets and the later consequence on food prices are presently rather unexplained. In order to explore these issues, we develop a theoretical model where the futures markets are linked to the cash markets through their impact on private stock decisions. We start with the analytical framework developed by Stein (1987) who shows that introducing more speculators may destabilise commodity prices, reduce stocks and lead to welfare loss. The essence of his argument is that the participation of risk neutral speculators in futures markets can for a period of time change the informational content of prices. This inflicts an externality on risk averse commercial traders, leading them to reduce their willingness to store the commodity. Using this framework, one can explain the massive entry of index funds in agriculture futures markets during 2004-2006 by a portfolio diversification motive. This has contributed to maintain low stock levels by commercial hedgers during that period and hence sets the conditions for the subsequent price spike. This theory is consistent with available data on stocks which have been low from 2003 to 2007 (figure 3).

In the Stein's model, information of the different (spot and futures) market participants regarding uncertain market developments is of crucial importance. In fact Stein's main results depend on three critical assumptions. The first is that that the commodity market is subject to many economic risks, with some lasting over several periods. The second is that market participants receive different signals on these risks and process this information in different

[2] A useful review is available in the report by the Global Food Markets Group (2010).
[3] The issue of characterizing such operations into commercial or non commercial positions is still debated in the US. They have been classified by the CFTC as commercial practices for the past years through their portfolio diversification goals. They should not be classified as speculative positions in the future for their diversification capabilities but could be formally differentiated from traditional hedging practices of commodity trading companies.

ways. The third is that commodity producers are unable to adjust their production levels between periods. Regarding the first assumption, it is little questionable that there are many sources of risks in the world cereal markets inducing a natural price volatility, such as the climatic risks at the supply side, the sanitary risk on animal production translating into uncertain feed demands or even the risks created by public policy (on biofuels for instance). Regarding the second assumption, it is also little questionable that many variables are “poorly” measured, especially in the short run. Hence agents rely on proxies. Much obvious is the level of stocks like, but not exclusively, Chinese stocks. Feed demand is also difficult to assess. China became a net importer of cereals in 2004: does this mean that Chinese stocks were “empty” and/or that Chinese feed demand was underestimated and/or does it result from a change in Chinese storage policy? The “new” demand of cereals for biofuel production was also subject to measurement errors in the short run. Analysts may rely on the statistics on the intention of, or the building of biofuel refineries but this is only a proxy of their futures effective cereal demands.
On the other hand, the third crucial assumption in the Stein framework, i.e. fixed production levels over all periods, is clearly untenable. For instance, the 2008 world grain crop was the largest on record and 5% higher than in 2007. Even if improved growing conditions favours yields gains, all analysts agree that the previous price spike did generate a significant supply response.

Accordingly our methodological contribution in this paper is to expand the Stein’s model by allowing production response to spot and futures prices. We maintain a two period model and assume a lagged production response of one period. We also generalise the specifications of final demand functions in order to analyse the sensitivity of results to the elasticity of demand. Stein implicitly assumes a unitary price elasticity of demand which is too restrictive for soft commodities. Our model, as well the nested Stein model, is fully presented in the first section of this paper. The second section is devoted to the empirical calibration of our model and the analysis of results. It is indeed impossible to get a closed form solution that allows us to perform standard calculus of static comparative. So we calibrate the model with standard behavioral parameters and next perform sensitivity analysis on critical parameters. We focus the analysis on the effects of index funds on the optimal stock held by commercials before concluding.

1. Theoretical framework

Following Stein, we make several assumptions in order to make computations tractable. We consider a one commodity, two periods model which is sufficient to analyse the impact of futures trading on the first period ending stock. We also assume that storage costs and the risk-free interest rate are both null. Three agents intervene in the commodity cash and futures markets. First, final consumers are assumed to be risk neutral. They buy their desired quantities on the cash market and do not participate in the futures market. Second, producers are assumed to be risk averse (with constant absolute risk aversion) and have three functions: they physically produce the commodity, they can store it and they can participate in the futures market for hedging purpose. Finally, commodity index funds only participate in the futures market and are assume to be risk neutral in order to simplify computations. This assumption is not so severe if the considered soft commodity has a small weight in the index fund portfolio, which is currently the situation[4].

[4] DJ UBS and S&P GSCI had respectively 28 and 14 % agricultural soft commodity shares in 2008

As stated in the Stein model, there are two sources of risks at each period that are out of control of producers.[5] One is a permanent shock occurring over the two periods that all agents have difficulty to quantify. The second is a periodic temporary shock that producers only are able to observe. In practice, one may consider the climate change effects or the feed demand effects as the permanent shock and the yearly pest impact as the temporary shock.

Like Stein we first compute market equilibriums over the two periods first without and then with futures markets in order to assess the effects of the commodity index funds.

a- No futures markets

The behaviour of final consumers is summarised by the following linear demand function (using usual notation):

$$D_1 = a_1 - b_1.P_1 \qquad (1)$$
$$D_2 = a_2 - b_2.P_2 \qquad (2)$$

The per period commodity supply is the sum of expected/planned production by producers (noted Y_i) and the two sources of risk, denoted X for the permanent shock and Z_i for the temporary shock:

$$S_1 = Y_1 + X + Z_1 \qquad (3)$$
$$S_2 = Y_2(.) + X + Z_2 \qquad (4)$$

In the Stein model, the expected productions are null. To the contrary we assume that the first period production is exogenous and depends on previous decisions. The production level of the second period is optimally determined by risk averse producers. Allowing producers to store part of supply from the first period to the second period leads to the following market equilibrium conditions:

$$a_1 - b_1.P_1 + I = Y_1 + X + Z_1 \qquad (5)$$
$$a_2 - b_2.P_2 - I = Y_2(.) + X + Z_2 \qquad (6)$$

Like Stein, we abstract from the initial first period level of stocks as well as from the final second period stocks. We also assume that stocks are netted out over the two periods. Both assumptions are clearly questionable but useful to get tractable analytical solutions. Above all these assumptions are maintained throughout the paper so that we are able in that context to analyse the impact of adding production response to the Stein model.

Accordingly prices between the two periods are linked by:

$$P_2 = \frac{1}{b_2}(a_1 + a_2 - Y_1) - \frac{1}{b_2}(2.X + Z_1 + Z_2) - \frac{Y_2(.)}{b_2} - \frac{b_1}{b_2}.P_1 \qquad (7)$$

[5] This can be motivated by additive production risks or alternatively by the existence of many producers in different countries, with some producers being risk neutral.

When futures trading is not possible, then risk averse producers optimally determine their optimal storage level and second period production level in order to maximise their expected utility. Their strategy is given by:

$$\max \quad I.(E_F(P_2) - P_1) + Y_2 E_F(P_2) - C(Y_2,.) - 0.5.\rho.(I + Y_2)^2.V_F(P_2) \tag{8}$$

ρ is the risk aversion parameter and $C(.)$ the total cost function. Assuming a quadratic cost function, the optimal production and stock are given by:

$$I + Y_2 = \frac{E_F(P_2) - P_1}{\rho.V_F(P_2)} \tag{9}$$

$$Y_2 = \frac{P_1 - c}{d} \tag{10}$$

To determine these quantities, we need to compute the second period price expectations of producers. We assume that producers have rational expectations. Hence they know all behavioural parameters, observe the first period level of production, price and the exact level of the temporary shock. From this set of information and the first period market equilibrium condition (equation 5), they are able to infer the exact level of the permanent shock. Accordingly, we have:

$$E_F(P_2) = \frac{1}{b_2}(a_1 + a_2 - Y_1) - \frac{1}{b_2}(2.X + Z_1) - \frac{\frac{P_1 - c}{d}}{b_2} - \frac{b_1}{b_2}.P_1 \tag{11}$$

$$V_F(P_2) = \frac{V(Z_2)}{b_2^2} \tag{12}$$

Hence the optimal level of stocks is given by:

$$I = -\frac{P_1 - c}{d} + \frac{b_2.\left(a_1 + a_2 - Y_1 - 2.X - Z_1 + \frac{c}{d} - \left(\frac{1}{d} + b_1 + b_2\right).P_1\right)}{\rho.V(Z_2)} \tag{13}$$

Plugging this inventory demand function into the equilibrium condition for the first period leads to the first period equilibrium price:[6]

[6] This expression corresponds to equation 17 of Stein if we assume that $a_i = 0, b_i = 1, c = 0, d \approx \infty$ and that the number of producers equal one.

$$P_1\left(b_1+\frac{1}{d}+\frac{b_2.\left(\frac{1}{d}+b_1+b_2\right)}{\rho.V(Z_2)}\right)=\left(a_1-Y_1+\frac{c}{d}\right).\left(1+\frac{b_2}{\rho.V(Z_2)}\right)+\frac{b_2.a_2}{\rho.V(Z_2)}$$
$$-X.\left(1+\frac{2.b_2}{\rho.V(Z_2)}\right)-Z_1.\left(1+\frac{b_2}{\rho.V(Z_2)}\right) \qquad (14)$$

As expected, the equilibrium price in the first period negatively depends on the supply shocks. The impact of the permanent shock is greater than the impact of the first period transitory shock. We can also check that the impacts of these shocks on first period price decrease when final demand become more price elastic. These impacts increase with the producer risk aversion and the variance of the second period temporary shock. In other words, if producers become more risk averse, they reduce their storage level and hence the first period equilibrium price. Equivalently, if the second period shock becomes more variable, producers prefer to reduce their stock that must be released in the second period.

Finally it is interesting to compare this price equilibrium function with the one when the second period production response equals zero. The counterpart to equation (14) is given by:

$$P_1\left(b_1+\frac{b_2.(b_1+b_2)}{\rho.V(Z_2)}\right)=(a_1-Y_1).\left(1+\frac{b_2}{\rho.V(Z_2)}\right)+\frac{b_2.(a_2-Y_2)}{\rho.V(Z_2)}$$
$$-X.\left(1+\frac{2.b_2}{\rho.V(Z_2)}\right)-Z_1.\left(1+\frac{b_2}{\rho.V(Z_2)}\right) \qquad (14')$$

There are only two differences between equations 14 and 14'. First the constant term now involves the exogenous second period production rather than the origin of the cost curve. Second the slope of the cost curve disappears in the left hand term. Hence the more price elastic the supply response is (d becomes smaller), the less the final price is sensitive to supply shocks.

b- With futures markets

We now introduce future markets assuming that participation in these markets is cost free. On the other hand, Grossman and Stiglitz (1980) or Andersen (1990) for instance assume the presence of transaction costs that explain the absence of some future markets. In our analysis, we abstract from these issues and assume the existence of these futures markets because agents have different information sets and/or beliefs. Again this assumption is shared with Stein' analysis.

Futures trading allow commodity index funds, as well as producers, to speculate on futures prices[7]. It also allows producers to partially/completely hedge their production and stocks. All these decisions depend on the information that is gathered by these economic agents. Following Stein, we assume that index funds are not able to precisely observe the first period temporary shock as much as the producers do. We also assume that they have noisy

[7] In the real life, the net commodity index funds position is hedged on the futures market through swap dealers

information on the permanent shock. That is they do not observe the permanent shock X; they rather observe the signal that first period supply is modified by $SI = X + W_1$. The main issue is that producers are no longer able to infer the permanent shock from the introduction of index funds in futures trading. This is so because futures prices and spot prices are now linked.

The program of producers is now given by:

$$\max \quad I.(E_F(P_2) - P_1) + F_F.(E_F(P_2) - P_f) + Y_2 E_F(P_2) - C(Y_2) \\ -0.5.\rho.(I + Y_2 + F_F)^2.V_F(P_2) \tag{15}$$

The optimal stock, second period production and hedging levels are given by:

$$I + Y_2 + F_F = \frac{E_F(P_2) - P_1}{\rho.V_F(P_2)} \tag{16}$$

$$Y_2 = \frac{P_1 - c}{d} \tag{17}$$

$$P_f = P_1 \tag{18}$$

Because storage is costless and producers can hedge their production and stock, future price and spot price are equal.

With the introduction of index funds and thus expectations of two economic agents, it is no longer possible to obtain a closed form solution to the first period equilibrium price like presented in equation (14). However it is possible to numerically compute the parameters of this equation. We thus search the conditions that these parameters must satisfy. As in the no futures market case, we look for a linear price equilibrium solution:

$$P_1 = \alpha_O + \alpha_X X + \alpha_Z Z_1 + \alpha_W W_1 \tag{19}$$

Using equations (19), (7) and (17), we obtain the second period price as a function of shocks and behavioural parameters:

$$P_2 = \frac{1}{b_2}(a_1 + a_2 - Y_1 + \frac{c}{d}) - \left(\frac{1}{d.b_2} + \frac{b_1}{b_2}\right).\alpha_O - \frac{1}{b_2} Z_2 - \\ -\left(\frac{2}{b_2} + \frac{\alpha_X}{d.b_2} + \frac{\alpha_X.b_1}{b_2}\right).X - \left(\frac{1}{b_2} + \frac{\alpha_Z}{d.b_2} + \frac{\alpha_Z.b_1}{b_2}\right).Z_1 - \left(\frac{\alpha_W}{d.b_2} + \frac{\alpha_W.b_1}{b_2}\right).W \tag{20}$$

Commodity index funds are assumed to be risk neutral in their positions on agricultural commodity futures contracts. Their net long/short position is also assumed to be a linear function of the observation made by index funds, i.e. spot prices and their signal on the first period supply shocks:

$$F_s = \delta + \eta.P_1 + \mu.(X + W_1) = \delta + \eta.\alpha_0 + (\eta.\alpha_X + \mu)X + \eta.\alpha_Z Z_1 + (\eta.\alpha_W + \mu)W_1 \tag{21}$$

Index funds are assumed rational in their use of available information. In particular they know that storage is costless. Given their information, their expected price change is zero:

$$E_S\left(P_2 - P_1 \middle| P_1\right) = E_S\left(P_2 - P_1 \middle| SI\right) = 0 \tag{22}$$

These two conditions imply the three following restrictions on the unknown parameters of the equilibrium price function (19) (our derivation is similar to Stein and available on request):

$$\alpha_O = \frac{a_1 + a_2 - Y_1 + \frac{c}{d}}{\frac{1}{d} + b_2 + b_1} \tag{23}$$

$$\begin{aligned}&\left(\frac{2}{b_2} + \frac{\alpha_X}{d.b_2} + \frac{\alpha_X .b_1}{b_2} + \alpha_X\right).\alpha_X .V(X) + \left(\frac{1}{b_2} + \frac{\alpha_Z}{d.b_2} + \frac{\alpha_Z .b_1}{b_2} + \alpha_Z\right).\alpha_Z .V(Z_1)\\ &+\left(\frac{\alpha_W}{d.b_2} + \frac{\alpha_W .b_1}{b_2} + \alpha_W\right).\alpha_W .V(W_1) = 0\end{aligned} \tag{24}$$

$$\left(\frac{2}{b_2} + \frac{\alpha_X}{d.b_2} + \frac{\alpha_X .b_1}{b_2} + \alpha_X\right).V(X) + \left(\frac{\alpha_W}{d.b_2} + \frac{\alpha_W .b_1}{b_2} + \alpha_W\right).V(W_1) = 0 \tag{25}$$

In order to determine the optimal level of stocks held by producers, we need to compute their expectations concerning the mean and variance of the second period price. They are able to observe the spot price and the temporary shock. On the other hand, they are no longer able to determine the permanent shock. The conditional expected mean and variance are given by (again we follow Stein to derive these expressions):

$$\begin{aligned}E_F(P_2) = &\frac{1}{b_2}(a_1 + a_2 - Y_1 + \frac{c}{d}) - \frac{Z_1}{b_2} - \left(\frac{1}{d.b_2} + \frac{b_1}{b_2}\right).P_1 -\\ &-\frac{2}{b_2}.\frac{\alpha_X .V(X)}{\left(\alpha_X^2 .V(X) + \alpha_W^2 .V(W_1)\right)}(\alpha_X .X + \alpha_W .W_1)\end{aligned} \tag{26}$$

$$\begin{aligned}V_F(P_2) = &\frac{V(Z_2)}{b_2^2} + \left(\frac{2}{b_2} + \frac{\alpha_X}{d.b_2} + \frac{\alpha_X .b_1}{b_2}\right)^2 .\frac{\alpha_W^2 .V(W_1)}{\alpha_X^2 .V(X) + \alpha_W^2 .V(W_1)}\\ &+\left(\frac{\alpha_W}{d.b_2} + \frac{\alpha_W .b_1}{b_2}\right)^2 .\frac{\alpha_X^2 .V(X)}{\alpha_X^2 .V(X) + \alpha_W^2 .V(W_1)}\end{aligned} \tag{27}$$

At this stage, it is interesting to compare these expressions to those we obtain in the no futures case (equations 11 and 12). The expressions (26) and (11) are very similar, except the fact that the permanent shock is no longer known for sure by producers. Hence the variability of this permanent shock now appears in the expected mean price. We also find that the noisy signal perceived by index funds has an impact of expected mean price by producers because they both participate in futures trading. As expected, the variance computed by producers for the second period price is now higher because producers have less sure information.

We are ready to express the inventory demand by producers by plugging (17), (21), (26), (27) into (16). So doing we logically assume that the futures market is in equilibrium, i.e. that the net long/short position of index funds is exactly matched by net short/long position by producers. The resulting demand of stocks is:

$$
\begin{aligned}
I = & -\frac{\alpha_0 + \alpha_X X + \alpha_Z Z_1 + \alpha_W W_1 - c}{d} + \\
& \delta + \eta.\alpha_0 + (\eta.\alpha_X + \mu)X + \eta.\alpha_Z Z_1 + (\eta.\alpha_W + \mu)W_1 + \\
& \left(\rho. \left(\begin{array}{l} \dfrac{V(Z_2)}{b_2^2} + \left(\dfrac{2}{b_2} + \dfrac{\alpha_X}{d.b_2} + \dfrac{\alpha_X.b_1}{b_2}\right)^2 . \dfrac{\alpha_W^2.V(W_1)}{\alpha_X^2.V(X) + \alpha_W^2.V(W_1)} \\ + \left(\dfrac{\alpha_W}{d.b_2} + \dfrac{\alpha_W.b_1}{b_2}\right)^2 . \dfrac{\alpha_X^2.V(X)}{\alpha_X^2.V(X) + \alpha_W^2.V(W_1)} \end{array} \right) \right)^{-1} . \\
& \left(\begin{array}{l} \dfrac{1}{b_2}(a_1 + a_2 - Y_1 + \dfrac{c}{d}) - \left(\dfrac{1}{d.b_2} + \dfrac{b_1}{b_2} + 1\right).\alpha_0 \\ - \left(\dfrac{2}{b_2}\dfrac{\alpha_X.V(X)}{\left(\alpha_X^2.V(X) + \alpha_W^2.V(W_1)\right)} + \dfrac{1}{d.b_2} + \dfrac{b_1}{b_2} + 1\right).\alpha_X.X \\ - \left(\dfrac{1}{b_2} + \dfrac{\alpha_Z.b_1}{b_2} + \dfrac{\alpha_Z}{d.b_2} + \alpha_Z\right).Z_1 \\ - \left(\dfrac{1}{d.b_2} + \dfrac{b_1}{b_2} + 1 + \dfrac{2.\alpha_X.V(X)}{b_2.\left(\alpha_X^2.V(X) + \alpha_W^2.V(W_1)\right)}\right).\alpha_W.W_1 \end{array} \right)
\end{aligned} \qquad (28)
$$

This expression is obviously quite complex and difficult to interpret. One must still note that it is linear in the supply shock variables. The first line corresponds to the second period optimal production, the second line to the level of futures trading and the last two lines to the expected price changes divided by the expected variance of the second period price.

Finally plugging this optimal stock demand in the first period market equilibrium condition (5) gives us four additional constraints on structural parameters:

$$
\begin{aligned}
& 1 + b_1.\alpha_X + \frac{\alpha_X}{d} - \eta.\alpha_X - \mu + \left(\rho.V_F(P_2)\right)^{-1}. \\
& \left(\frac{2}{b_2}\frac{\alpha_X^2.V(X)}{\left(\alpha_X^2.V(X) + \alpha_W^2.V(W_1)\right)} + \frac{\alpha_X}{d.b_2} + \frac{\alpha_X.b_1}{b_2} + \alpha_X\right) = 0
\end{aligned} \qquad (29)
$$

$$
\begin{aligned}
& 1 + b_1.\alpha_Z + \frac{\alpha_Z}{d} - \eta.\alpha_Z + \left(\rho.V_F(P_2)\right)^{-1}. \\
& \left(\frac{1}{b_2} + \frac{\alpha_Z}{d.b_2} + \frac{\alpha_Z.b_1}{b_2} + \alpha_Z\right) = 0
\end{aligned} \qquad (30)
$$

$$1+b_1.\alpha_W+\frac{\alpha_W}{d}-\eta.\alpha_W-\mu+\left(\rho.V_F\left(P_2\right)\right)^{-1}.$$
$$\left(\frac{2}{b_2}\frac{\alpha_X.\alpha_W.V(X)}{\left(\alpha_X^2.V(X)+\alpha_W^2.V(W_1)\right)}+\frac{\alpha_W}{d.b_2}+\frac{\alpha_W.b_1}{b_2}+\alpha_W\right)=0 \quad (31)$$

$$\delta=Y_1-a_1-\frac{c}{d}+\left(b_1+\frac{1}{d}-\eta\right).\alpha_0 \quad (32)$$

We thus get a square system of seven conditions (23, 24, 25, 29, 30, 31, 32, 33) and seven unknown parameters ($\alpha_0,\alpha_X,\alpha_Z,\alpha_W,\delta,\eta,\mu$) which characterize equilibrium functions when futures trading is allowed. This system generalises Stein ones by working in levels (rather on deviation from trends, hence the introduction of constants in our setting) and by the introduction of production response.[8]

If the second period production is assumed fixed, then this system of equations must be slightly modified. First all terms where the d parameter is involved are removed. Second the constant of the price equilibrium function is given by:

$$\alpha_O=\frac{a_1+a_2-Y_1-Y_2}{b_2+b_1} \quad (23')$$

2. Empirical results

When futures trading is allowed, we are unable to get an analytical solution to the first period price equilibrium function. We thus need to turn to empirical calibration. This is always subject to criticism because behavioural parameters are never perfectly known. Hence we will perform a sensitivity analysis of our results to these parameters. To make results as clear as possible, we always calibrate structural parameters such as, without supply shocks, final demands, production levels and prices equal 100 in both periods. We also assume that all random variables (X,Z,W) are normal with means equal to zero and variance equal to 4. On the other hand, we will consider different values of price elasticity of demand and supply as well as different values for the risk aversion parameter.

a. Standard calibration

In the base case, we assume that the price elasticity of final demand equals minus one half in both periods (hence values of the constant a and the slope b are respectively 150 and 0.5). When supply response is allowed, we assume that the supply price elasticity equals one (hence values of constant c and slope d are respectively zero and one). Finally we assume that the risk aversion coefficient equals one. Results on price equilibrium functions, inventory decisions and futures trading are provided in table 1.

[8] Again we end up with Stein system of conditions if we impose $a_i=0,b_i=1,c=0,d\approx\infty$ and that the number of producers equals one. Stein provides proofs of existence and uniqueness of solution in this particular context. We also check empirically the stability of solutions.

i/ Without production response

Without supply response and futures trading (first row of Table 1), we find as expected that the optimal stock only depends on the first period temporary shock. For instance, if this first period temporary supply shock is positive, then producers increase their stock by 10 per cent of this shock. This reduces the drop of the first period price: it only decreases by 180 per cent rather than by 200 per cent (due to the 0.5 price elasticity of demand). By definition, the demand of storage does not depend on the permanent shock and on the noisy signal perceived by index funds.

When futures trading is allowed (second row of Table 1), producers and index funds can now speculate on second period prices. As Stein, we find that this modifies the optimal stock level even if the current noisy signal (W) equals zero. This is so because the variance of this noisy signal is different from zero and thus producers consider that index funds may define their futures position with imperfect information. It appears that this optimal stock level negatively depends on the noisy signal perceived by index funds. The same negative relationship also exists with the net long position of index funds. For example, if index funds receive the signal that there is a much higher supply shock than in reality, they prefer to be short rather than long on futures markets. This information is transmitted to producers who then prefer to decrease their stock level. This is an example of the information externality revealed by Stein.

More interesting to us is the impact of futures trading on the optimal stock level. This impact positively depends on the permanent and transitory shocks (the multipliers are respectively equal to 0.15 and 0.24) and negatively on the noisy signal perceived by index funds (the multiplier equals -0.15). It is quite easy to find cases where optimal stocks are reduced due to the introduction of futures trading. For example, if there is no permanent shock (X=0) but simply a temporary shock equal to one unit (Z=1), then the optimal stock equals 0.1 unit when futures trading is not allowed. If index funds receive the wrong signal that total supply increases by two units (without being able to determine if this is permanent or not, SI=2), then their net long position equals 22.96 units and the optimal stock level is equal to 0.04 unit.

In this simple example, the introduction of futures trading and index funds with imperfect information lowers the optimal stock by 60%. Such framework may explain why stocks remain low during 2004-2006 when index funds increase their net long positions on agricultural commodity futures. On this ground, one may conclude that index funds set the conditions, through low stock levels, to the subsequent price spike. However this assertion neglects the possibility for producers to optimally adjust their second period volume of production. Is the result robust to this potential adjustment ? This is what we examine now.

ii/ With production response

When producers have the possibility to adjust their second period production level, the equilibrium functions are completely different. Let's start again without futures trading (fourth row of table 1). We find that the optimal inventory level now depends on the permanent shock and has a constant negative term.[9] The economic interpretation of the

[9] One may object that inventory levels can never be negative. As already noted, we do not introduce initial (first period) and final (second period) levels of stocks in the model to simplify the analysis and focus our contribution on supply side responses. Adding an exogenous positive stock held by consumers (through the constant term of

negative constant term is the following. Producers are risk averse. Without any risk management tools, they want to reduce their optimal second period production level which is subject to price risk. When futures trading is ruled out, they only have the storage instrument to mitigate the impact of second period price risk on their production. By reducing rather than increasing their stocks, the first period equilibrium price is lower and hence this reduces the second period optimal production level. In addition, these two decisions (reduced stocks and second period production level) reduce the total expected supply in the second period. This is beneficial to producers if the demand is price inelastic. The positive impact of the permanent shock on the optimal stock level can be explained by another economic mechanism. The specification of a supply function is inducing a more price elastic net demand (final demand minus production) in the second period . Hence, even if this permanent shock is also observed in the second period, its negative price impact will be less important that year. It is thus the interest of producers to smooth this supply shock towards the more elastic period.

When futures trading is allowed (fifth row of Table 1), producers have now two possibilities to cope with the second period price risk. They can transfer this risk to futures markets in addition to manage their storage level. The optimal level of stocks has no longer a negative constant because producers now use futures trading to hedge their second period supply. This is also apparent in the higher constant of the net long position of index funds. We again find that the noisy information brought by index funds has always a negative influence on both the optimal inventory level and the funds net long position.

More important is the last row of Table 1. It shows that when production response by producers is allowed, opening futures trading always increases the optimal stock level (given our assumptions on the distribution of supply shocks). So the previous conclusion that index funds did contribute to the food price spike by maintaining low pre-spike stocks was not robust. The intuition is quite simple. Futures trading facilitates supply decisions by producers. This beneficial risk sharing effect largely overcomes the impact of informational externalities brought by index funds.

b. Sensitivity analysis

We have to test the sensitivity of our main result to the assumptions regarding price elasticity of demand, price elasticity of supply and risk aversion parameter. We focus on the impact of allowing futures trading on the optimal stock level. Results are reported in Table 2.

It appears that our main result is highly robust. When the supply response to price is ruled out, the possibility that index funds lower the optimal stock level through an informational externality is likely. On the other hand, this is unlikely when the supply response is introduced. This high robustness of our main result certainly has to do with the assumptions of rational economic agents. Following Stein, the assumption maintained throughout the paper is that they are all able to perfectly observe structural parameters. They only suffer from information externalities on supply shocks.

Regarding the risk aversion parameter, we also see little influence and the directions of the effects are as expected. For instance, the constant term of the optimal inventory level

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final demand) does not modify the analysis (only the constants of the equations 19 and 21) are modified while ensuring that ending stocks never become negative.

increases from 28.57 to 31.58 because hedging demand by producers increase with their risk aversion.

Conclusion

The role played by "speculators" in the 2007/08 commodity price spike is lively disputed. Analyses conducted so far mainly focus on their behaviour during the price spike through statistical methods. In this article we focus our analysis on the increasing participation of commodity index funds in agricultural futures markets before the agricultural price spike. Our central theme is to determine if their pre-spike massive entry does prepare the subsequent crisis by maintaining low stock levels.

In that respect, we develop a theoretical model explaining the behaviour of non commercial and commercial traders on commodity cash and futures markets. Following Stein, we allow index funds to inflict an informational externality on commercial traders and hence to reduce their desire to hold stock. We find that, if commercial traders cannot modify their futures production decisions, then the negative impact of index funds on optimal stocks is possible. This is because stock is the only means commercial traders have to cope with futures price risks. However this negative impact is very unlikely when production can be adjusted. Futures trading indeed facilitates supply decisions of producers. Our empirical assessment shows that this beneficial risk sharing effect largely overcomes the informational externalities brought by index funds. We also find that this positive impact of index funds on optimal stock is highly robust to all behavioural parameters.

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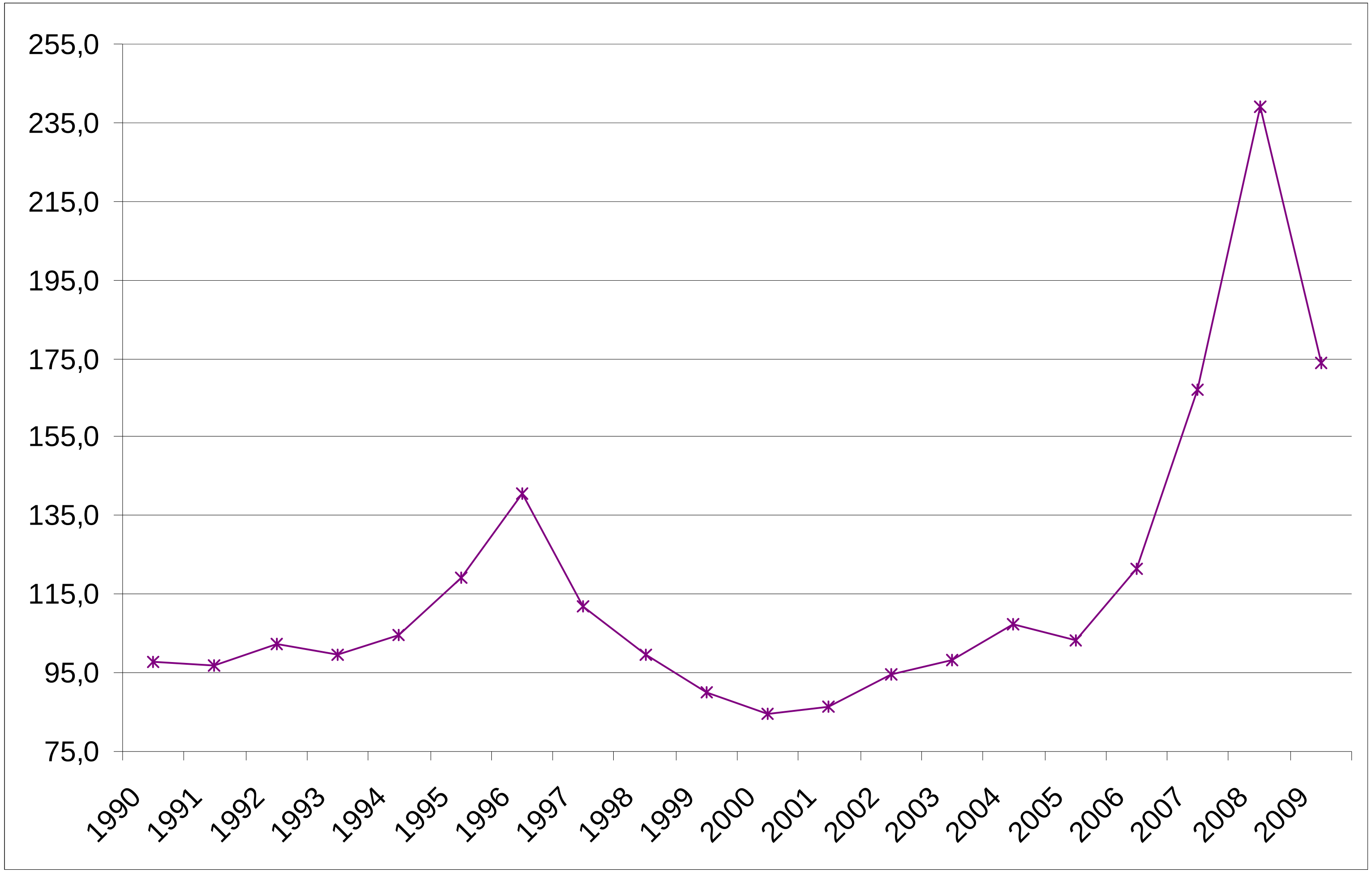
Table 1. Impacts of futures trading with and without supply response

	Constant	Permanent shock X	Temporary shock Z	Noisy signal W
Without supply response				
Without futures trading				
First period price	100	-2	-1.80	0
Inventory level	0	0	0.10	0
With futures trading				
First period price	100	-1.70	-1.32	-0.30
Inventory level	0	0.15	0.34	-0.15
Funds long position	22.94	0.18	0.30	-0.14
Impact of futures trading				
Inventory level	0	0.15	0.24	-0.15
With supply response				
Without futures trading				
First period price	42.85	-0.71	-0.64	0
Inventory level	-28.57	0.64	0.68	0
With futures trading				
First period price	100	-0.85	-0.66	-0.15
Inventory level	0	0.57	0.67	-0.07
Funds long position	96.18	-0.25	-0.02	-0.22
Impact of futures trading				
Inventory level	28.57	-0.07	-0.01	-0.07

Table 2. Impacts of futures trading on optimal inventory levels with and without supply response: sensitivity to demand elasticity, production elasticity and risk aversion

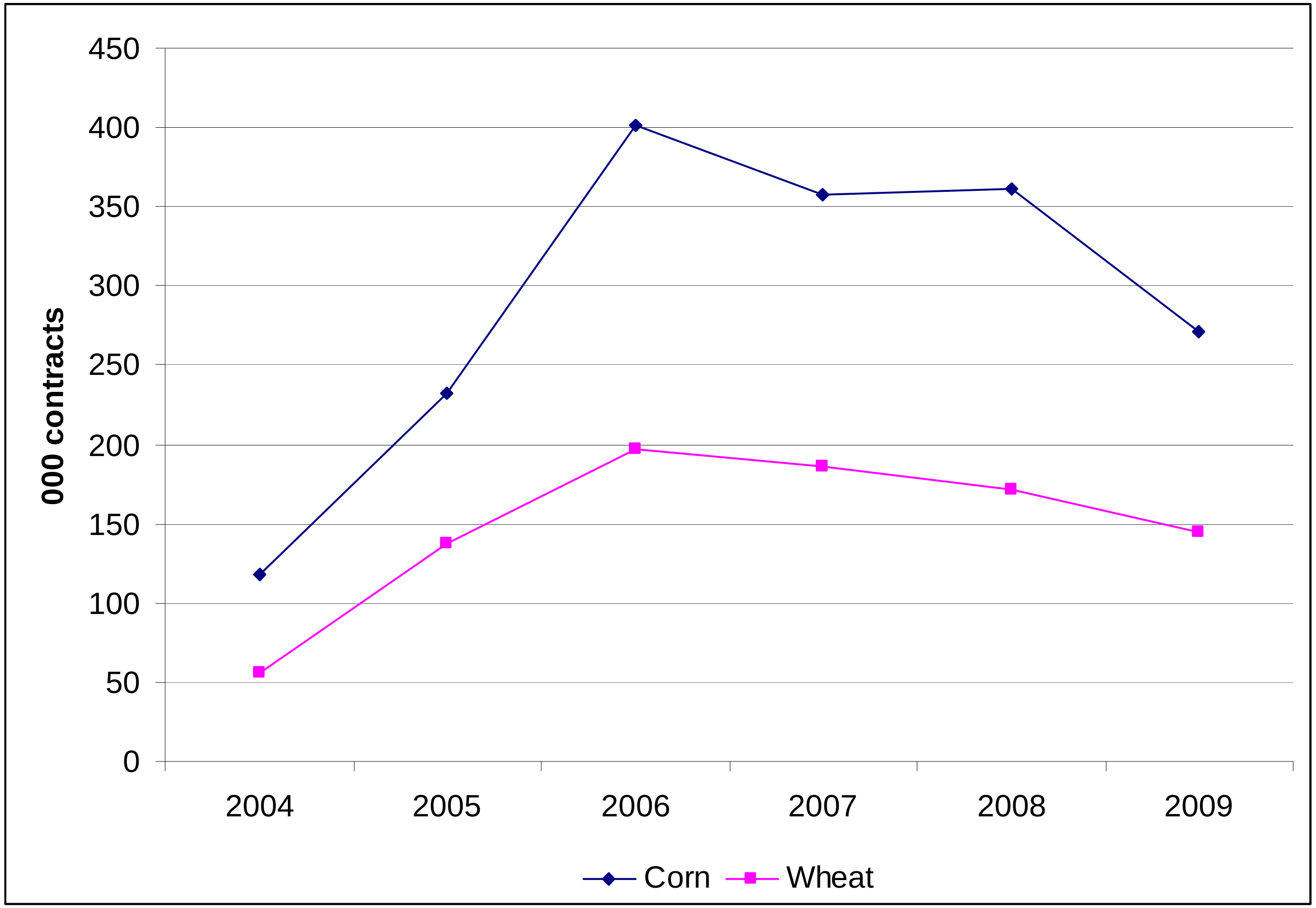
	Constant	Permanent shock X	Temporary shock Z	Noisy signal W
Base values : demand elasticity = - 0.5, production elasticity = 1, risk aversion = 1				
Without supply response	0	0.15	0.24	-0.15
With supply response	28.57	-0.07	-0.01	-0.07
Elastic demand : demand elasticity = - 2, production elasticity = 1, risk aversion = 1				
Without supply response	0	0.11	0.12	-0.11
With supply response	36.36	-0.01	0.04	-0.08
Inelastic supply : demand elasticity = - 0.5, production elasticity = 0.5, risk aversion = 1				
Without supply response	0	0.15	0.24	-0.15
With supply response	42.10	-0.07	-0.02	-0.05
Elastic supply : demand elasticity = - 0.5, production elasticity = 2, risk aversion = 1				
Without supply response	0	0.15	0.24	-0.15
With supply response	17.39	-0.07	-0.02	-0.05
Risk aversion : demand elasticity = - 0.5, production elasticity = 1, risk aversion = 3				
Without supply response	0	0.16	0.30	-0.16
With supply response	31.58	-0.08	-0.01	-0.08

Figure 1. World cereal price index (2002-2004 = 100)



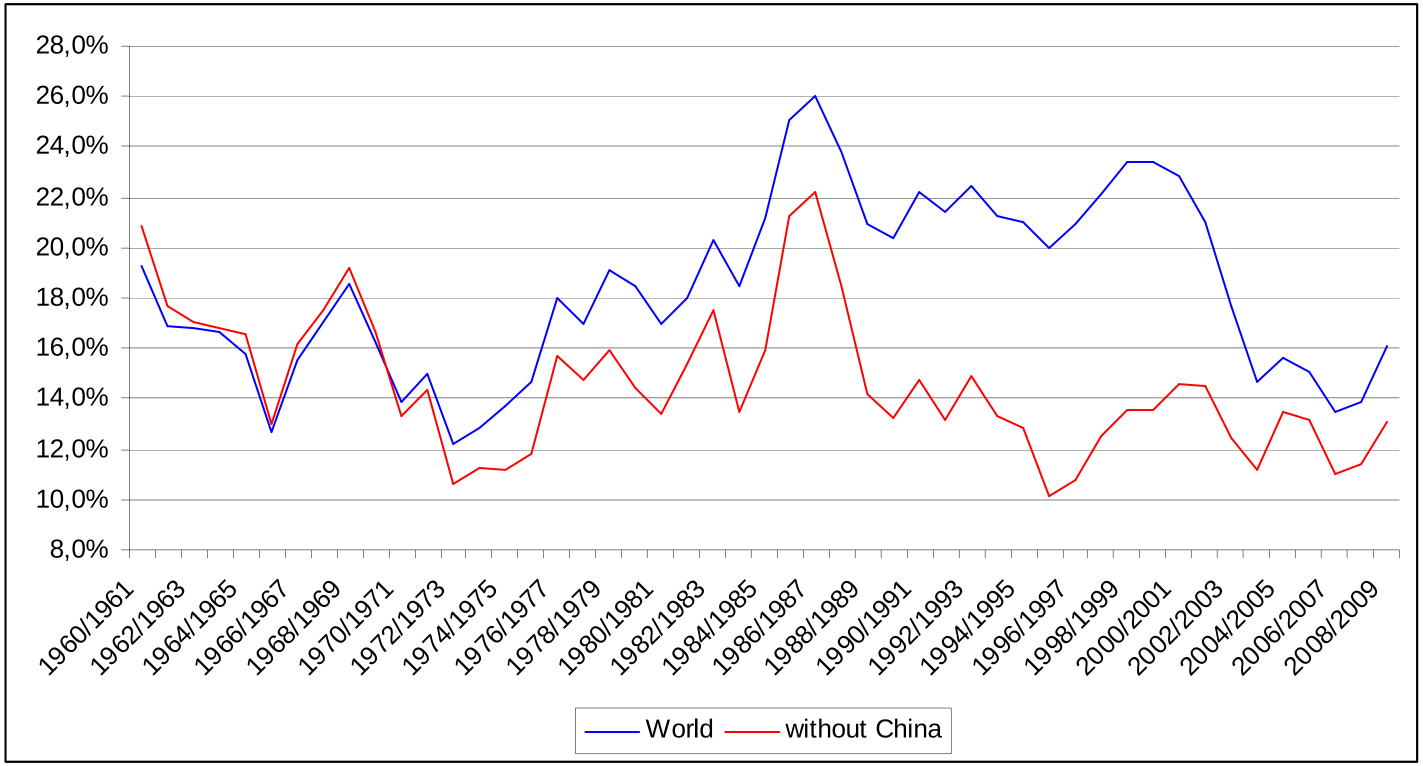
Source : FAO

Figure 2: Index fund net long number of contracts in the Chicago Mercantile Exchange



Source: The Global Food Markets Group (2010)

Figure 3. World stock to use ratios of main cereals (rice + corn + wheat)



Source: USDA –Production Supply and Distribution