COMMODOITY PRICE VOLATILITY: CAUSES AND IMPACT ON THE EU AGRICULTURAL MARKETS

NOTE

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Abstract:

Agricultural macroeconomic modelling has not yet adapted to the complexity of today’s world and cannot account for observed price volatility. Modelling financialized commodity markets requires a dynamics of anticipations under risk intertwined with economic dynamics, as defined here. Markets volatility doesn’t have one single cause and should be studied within global interconnected markets. Speculation appears as one major factor, together with monetary policy and some other well-known ones. Full liberalization of agriculture, if anything, should increase present volatility. Steps to limit volatility are suggested. The World GCE Momagri model could help defining a consistent policy in this respect.
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Introduction

“The equilibrium state of production is like the equilibrium state of exchange, an ideal state, not a real one. It never materializes [...]”
L. Walras (1878)\(^1\)

Markets evolve, so should markets’ theories do and, to a large extent, they effectively do so\(^2\). But many models used for practical policies lag behind. Policy makers often use models of yesterday – or, indeed, general ideas derived from those models - to try disentangling nowadays issues. Inevitably under such conditions, one is at pain understanding facts. Our world has become a complex system, evolving according to trajectories which may suddenly change, and we still try to understand agricultural evolution by using, at the macroeconomic international level at least, more or less sophisticated versions of a mechanical supply and demand scheme explicitly elaborated as an approximation (see Walras’ assertion in front of this text). And Walras’ world was yet way simpler than ours! The image of the auctioneer illustrates how this approximation of markets functioning works: Everybody having revealed some given disposition to buy or to sell at a personally quoted price, the market maker (taken as an auctioneer) would only allow effective transactions once the price balancing supply and demand has been determined (the so-called tâtonnement process of economic theory, or the ‘fixing’ process in stock exchanges). This hypothesis and its natural extension of rational expectations\(^3\) rule out, for example, any multiplicity of market prices, any kind of volatility of prices in the long run, and simply assumes out many other important features of market structure (information, uncertainty, etc.) and of competitive behaviour (efforts, adaptive expectations, bounded rationality, etc.). That approximation can therefore help under certain conditions only. This paper shows that agriculture doesn’t meet these conditions and elaborates a hopefully more meaningful because more realistic model. Volatility appears then as a natural phenomenon we have to live with and to some extent tame.

It makes sense to think that meeting these conditions were widespread at the beginning of the XXth Century, but they are way less than universal in today’s world. Yet, many of today’s agricultural macroeconomic models appear as assuming that such conditions always describe our world. One can even say that a widespread modelling practice sees our world as having once become just like these conditions and elaborates reasoning on this exclusive basis. This, in our view, has been a deep source of counterproductive policies based on an epistemological mistake and in some cases simply historical pieces of nonsense. Agriculture is one of the latter cases. The Momagri world model aims at offering a possible solution to break this deadlock\(^4\).

\(^{3}\) Under the rational expectations hypothesis, economic agent’s anticipations at each period match the exact equilibrium price of the next period, or a least the average on a small interval of the potential values of this values of this equilibrium price. Under such a hypothesis, speculators making profits necessarily stabilize prices. This is the “stabilizing speculation” view, which is, again, relevant under certain conditions only.
\(^{4}\) When Momagri officers came to ask me for participation and coordination of a new world model, I first tended to decline the invitation as beyond my competencies. But I soon realized that something was to be done in this direction. We started to look at existing models and their technical features: We were appalled. Not only were...
Whatever the mathematical refinement of these concepts and tools of economics and econometrics, it does not bridge the gap for the complexity of our world and allow making predictions years ahead of commodity prices or outputs with some small interval error, like was done in the Fifties and Sixties. Such predictions of one of the widely used models in economic policy have proved to be consistently wrong (see figure 1).

**Figure 1. Consistent mistakes in predicting American agricultural output using one of the standard models in use**

To be sure, there are impressive macroeconomic models of agriculture with thousands of equations on agricultural issues. Most of their conclusions are roughly that commodity prices – oil, cereals, fruits, meat, and many others – should gently fluctuate by a few percent around their respective equilibrium levels, if only we were wise enough to get rid of markets barriers of all sorts and make the world look closely like the perfect market of the theory. And no one could deny that tremendous efforts have been put to that end in the last thirty years on the basis of such traditional models. Yet, during all that period, all the agricultural commodity prices we’ve just mentioned have been wildly fluctuating – unlike, interestingly, most industrial and services prices: Figure 2 offers an example of this fact. In recent years, moreover, the range of fluctuations of these products has become dazzling. While many gurus believed, at the beginning of the last decade, cereals prices to be consistently and smoothly increasing, they were surprised by the prevalence of fluctuations of these very prices, and of non-cyclical fluctuations. The worst example has been the fall of these prices – in some cases by almost 60% - experienced between April and December, 2008. At that last date, the prices of these same products were seen as falling due to the impact of the financial and economic crisis. Yet, that crisis is far from over and the prices have been meanwhile up and down again.

the links to environment and innovation missing in most cases, not to speak of the very notion of risk itself and of any idea of expectation, but the models were grounded on the set of hypotheses already evoked, overly restrictive for agriculture. And this has been all the more frightening because such model are used without their builders warning politicians and indeed policy advisors of the hypotheses made. We decided to take up the challenge and try providing a more appropriate tool to policymakers wherever they may be: this was the origin of the Momagri model, back in early 2006, focusing on the volatility issue. A first expression of our results is appearing in: Munier, B., 2010,”Boundedly Rational Exuberance on Agricultural Commodity Markets”, Risk and Decision Analysis, forthcoming. See also the interesting Comments by Semmler and Bernard there (forthcoming).
Figure 2. Differences in volatility between agricultural and industrial products

![Graph showing differences in volatility between agricultural and industrial products.](image)

Source: Chadwick Investment Group (sugar), and Economagic (tomatoes, automobiles)

Such mistakes in predicting prices and in anticipating volatility are understandable when looking at the grounding of some widely known and used models. If, for instance, we consider the World Bank Model mainly used to ground such assertions as the gains in welfare expected from global deregulation, etc. the following observations can be made:

1. The word “risk” is not mentioned a single time throughout the 103 page-long technical document.
2. The word “uncertainty” is mentioned only once, (p. 84) and said to be, in macroeconomics, “mainly linked to inflation”.
3. The word “climate” does not exist either throughout the said document and
4. The word “expectation” is evoked only once (p. 4) to be immediately ruled out in the model, which explicitly and exclusively explains markets situations through population increase, technological progress, accumulation of capital and productivity changes. There is thus room, by design, for some gentle price variations, never for anything like observed volatility in prices. What it means, for policy making, is that volatility is a phenomenon of secondary importance for economic welfare. We think (fig. 2) that this may be true for many sectors in industry and the services, but not for agriculture and for some other markets, among which the financial market, oil, electricity, most primary commodities, real estate being in-between. We should, however, have learned our lesson after all the economic crises lived since the seventies and in particular the exuberance of some markets in the last decade...

If we consider the 45 page long paper on the ‘Mirage’ Model, we can make similar observations: no effort is produced to introduce and model uncertainty in the behaviour of economic agents, even under the simplified form which economists call ‘risk’ (i.e. the case where uncertainty is measured by a single probability distribution, known by everybody, which is already restrictive). Be it for this reason or for some other one, the authors admit in their conclusion that, within their model “agriculture is modelled the same way as industry. Even if the model is not specifically designed to evaluate commercial agricultural policies, a more realistic description of that sector would be desirable”. Yet, they assert in the immediately following lines that economic modelling should call upon “well-identified and robust mechanisms” exclusively, leaving it to the users to interpret the results yielded by the model as to introduce the impact of non modelled variables: “the interpretation

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requires then an adjusted analysis, taking into account the set of problems which one focuses upon as well as the important mechanisms which are not considered in the model” (p. 137). But how should one do that ‘adjustment'? Do the authors care to explain which adjustment, on the basis of what?

This view of economic modelling is typical of a generation of economists and even, one could say, of the lost time of economic separation between nations. We cannot but offer a different view today. More specifically, we shall indeed argue here that the standard market model - in the sense where we described it at length here above – and its asserted adjustment is insufficiently relevant to present agricultural commodity markets, because it ignores the historical fact that agricultural commodity markets have become “financialized” ones, in the minimal sense where their respective outputs have come to be massively used as underlyings of financial operations. To be sure, this has been the case in the past during some periods and for some limited number of products of secondary significance, like coffee. But the scale and scope of the phenomenon have been considerably enlarged. This “financialization” has at least four consequences for economic modelling:

1) It has turned these markets into expectations driven. It is the dynamic **interplay between these social expectations and the natural-technical structure** of the agro-systems in use which is now the bone of the rationale of the evolution of these markets, not anymore the mere confrontation in one shot of supply and demand according to a tâtonnement process as recalled above.

2) A new category of players has appeared on these commodity markets, which has changed the type of behaviour of these markets. Indeed, **short-term investors** do not have a neutral role of self-cancelling intermediaries, so that they need to be modelled, be it only as a sort of Maxwell’s demons. There are many ongoing discussions as to whether speculators (an important subcategory of short term private investors) are leading the price game or not, but virtually everybody now credit them with some influence on these markets. Even researchers at IFPRI – who denied it until recently - have now started to acknowledge that there might be something to it7.

3) Financialization also means connections with the financial markets properly said, as well as with **monetary policy**. Most researchers agree on some role for monetary policy on commodity prices, but few models have tried to include it in some meaningful way, and the leading models have not done it altogether.

4) All markets have become more intensely interconnected at world level. This has at the same time stabilizing consequences when transportation costs are low and some kind of domino effect through financial transactions. More generally speaking, however, this means that policy making should look at the system as a whole, neither at a single market, nor at a few branches, but at a **general interconnection at world level**.

The present paper represents a new effort to tackle with these four issues, which we see as compelling in modelling agricultural markets. The model tries to offer an admissible solution to the issues raised above. It is organized as follows. Section 2 introduces the Momagri modelling approach, designed to give an account of volatility on commodity markets. Subsection will point to empirical facts justifying the approach. Section 3 sketches the impacts of volatility in terms of general economic welfare, briefly reminds that Europe’s CAP in its present state is not fit to cope with the issues involved and quotes possible steps to be taken. Section 4 concludes.

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1. Momagri’s agricultural modelling approach

1.1. The modular approach of Momagri

The modelling approach taken here wants to cope in an as simple as possible manner with the four guidelines just defined at the end of the introductory section.

To start with, we have looked at facts and used the GTAP 6.0 database, which we have reshuffled into a social account matrix defining ten “zones” of the world and 20 economic sectors within each zone. As a consequence, the model will interconnect 200 market sets.

This general interconnection will take place through a general equilibrium model (called further down the “central module”) which, in itself, innovates in its design. But taking into account the three other features of adequate market modelling as defined above requires representing, on the financialized agricultural commodity markets, the specific expectation formation of farmers, the short term investors’ expectation formation and behaviour and their interplay in agricultural price formation. This is done in a side model called the “risk module”, which interacts with the central model in a way which we explain in the next paragraph. This risk module entail five aggregate agricultural sectors: Cereals (CER), Fruits and vegetables (VFO), Fibers (CRF), Animal raising (LVA), Other sectors in Agriculture (OTA).

The same modular logic will be called upon to represent other aspects of agricultural markets as the role of innovation and intellectual property rights and as the interdependence with the environment. All these will be dealt with in “peripheral modules”, like the risk module, with which we start here. Meanwhile, more standard interdependencies like the energy market will be taken care of within the “central module”. For the time being, version 2 of our model emphasizes the role of market uncertainty in the emergence of price volatility.

1.2. The sequential approach to general interconnection

The central module and the risk module interact in the following way (figure 3):

1) In period t, the peripheral modules receive, each for its part, the relevant results obtained in the central module in period t-1.

2) During period t, every peripheral module is run separately, in parallel to each other.

3) Further in period t, the results obtained in each peripheral module are communicated to the Central Module.

4) The central module is finally run for period t with all the peripheral modules’ results taken as inputs, and the general equilibrium is computed.

5) Period t+1 is now ready to start, etc.
It can be seen immediately that the risk module’s results introduced during some period (say, t-1) into the central module as inputs of the latter, are the output prices of five major aggregated agricultural sectors. The central module is then run by taking these five prices as temporarily given and computes a first step of the new general equilibrium at period t-1.

**Figure 3. The example of the risk module in the version 2 of the momagri model**

Among the results at the end of period t-1 are the revenues of the five agricultural sectors. These revenues are then introduced into the risk module as inputs of the latter at period t, and the outputs of the risk module at period t “complement” the general equilibrium process.

In other words, we cut into two parts the general equilibrium process: agricultural prices → agricultural revenues through a first part of general equilibrium → agricultural prices anew to make general equilibrium complete. Needless to say, the central module has a “closure equation”. But the latter is considered here as a temporary device to be able to generate the prices and quantities looked for in two steps. With different words, our general equilibrium is computed in two stages, the closure of each is only temporary. This is related to the overly restrictive constraint that the Walrasian characteristics of the standard global models are imposing on economic analysis.

### 1.3. The risk module: introducing complexity in markets

The risk module consists in a partial out of equilibrium model of price formation for each agricultural sector, with producers, short term investors and final demand. The Walrasian equilibrium approximation is taken only as a “notional” reference, not as a realized state.

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8 The reader who would pressed for time may dispense reading the equations of this section. The text itself is self-explanatory, except for some technical considerations, which can be skipped by non-economically trained readers.
1.3.1. Notional reference

Supply behavior of farmers is derived from the production function in the associated Computable General Equilibrium (CGE) model:

\[ y_i = \frac{p_i}{d} \]  

(1)

The parameter \( d \) is kept constant, unless otherwise stated (changes in productivity or for specific reasons). The demand is represented the equation of the tangent to the constant elasticity demand function at the initial equilibrium point. We write, for \( t=0 \):

\[ x_0 = \frac{a_0}{b_0} - \frac{1}{b_0} p_0 \]  

(2)

So that the “notional” price of market equilibrium can be approximated, if not in “too” strong a disequilibrium, by the equation:

\[ PN \simeq \frac{a d}{b + d} \]  

(3)

As already argued – and confirmed by Walras himself above - we never can observe, at any period, the notional price \( PN \). Each farmer worries about his or her own farm and bases his or her decisions on his or her expectation. The latter may vary widely from one to the other and nothing says that there would always be a “market equilibrium” yielding \( PN \) (see for instance the Keynesian approach to supply), even if there were no other actors on the market.

1.3.2. Macro market sequences, expectation formation by producers

Agricultural producers form boundedly rational adaptive expectations. We assume that they combine an adaptive expectation scheme in the Nerlovian tradition with the main features of Allais’ model of memory (Allais, 1972).

Natural risk (among which the climatic aspect is most important, but not the only component) is certainly considered, but it is not – by far – the only source of uncertainty at world level in this model. This represents a major difference with the Newbery and Stiglitz (1981) dominant tradition among agricultural economists. A large part of uncertainty in our model is indeed endogenous, the exogenous ‘natural’ risk interfering with it. Both types of uncertainty have an immediate impact on price formation.

Figure 4: Macro-sequence on an agricultural market

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9 We would similarly be at pain to isolate, within the demand we infer from statistical data collected on the market, the part of it due to final consumers and the part of it due to intermediaries and/or investors, a small part of them willing to hold physical inventories, so we would make a specification error by using simply (2) to estimate final consumers’ demand.
Each year, farmers consider their “revenues”, which we take here to be the total gross selling value of their production, denoted by $R$. They recall an indicator $R_{m,t}$ of the revenues series in the past three years $R_{t-3}$, $R_{t-2}$, $R_{t-1}$ under the form of an exponentially increasing rate of forgetfulness $\zeta$, following Allais (1972):

$$R_{m,t} = \frac{R_{t-3}}{8} + \frac{R_{t-2}}{4} + \frac{R_{t-1}}{2} \quad (4)$$

They use a uniform law (law of equal probability given to all possible outcomes) to heuristically compute the average $E[\zeta_t(\bar{R}_{t-i,j})] = \bar{R}_{m,t}$ as an index of anticipated tendency and the variance $\sigma^2[\zeta_t(\bar{R}_{t-i,j})] = \sigma^2_{m,t}$ as an index of volatility. Not unlike many of our modern Pythias or gurus, farmers look in the rear mirror to form expectations:

$$P_{a,t} = \mu \frac{R_{a,t}}{R_{t-1}} + (1 - \mu)PN \quad (5)$$

Their anticipated price for period $t$, denoted by $P_{a,t}$, may be regarded as depending from $P_{r,t-1}$, i.e. the resulting price on the market at the end of period $t-1$, which they mix with the idea they form of the notional equilibrium price $PN$. In equation (5), $\mu$ is a given subjective parameter, $R_{t-1}$ stands for the revenue having obtained in the t-1 period, and $R_{a,t}$ for the anticipated revenue (certainty-equivalent) for the present period. We have therefore to give an expression of that anticipated revenue (in terms of certainty equivalent) $R_{a,t}$. The certainty equivalent (in Arrow-Pratt’s sense) to the empirically felt distribution of farmers’ revenues over the last years can be approximated as:

$$R_{a,t} = \bar{R}_{m,t} - \theta(R_{t-3}, R_{t-2}, R_{t-1}) \gamma \sigma^2_{m,t} / 2 \bar{R}_{m,t} \quad (6)$$

where relative risk aversion (RRA) of farmers is taken as $\gamma$ and considered to be a constant.

Farmers display individual behaviors towards risk which can be better captured by some form of the rank dependent model (Bouzit and Gleyzes, 1997, Serraõ and Coelho, 2004) than by mere expected utility. The certainty equivalent they use does therefore depend both on the Arrow Pratt coefficient associated to their utility function and on some transformation of the probability distribution considered (Hilton, 1988). Field experiments have however taught us that, while revealed von Neumann Morgenstern utility functions appear as fairly robust over time, the probability transformation function substantially depends on context. To give an account of this observation, we somehow modify the definition of optimism/pessimism in the rank dependent model literature, to make it part of the interdependence of subjective judgments and of the economic context in which they are formed (socio-technical dynamics evoked above):

$$\theta(R_{t-3}, R_{t-2}, R_{t-1}) = \frac{1}{C_1 + e^{C_3(R_{t-3} + R_{t-2} + R_{t-1})}} + C_2 \quad (7)$$

With three independent coefficients, as we set:

$$C_4 = \frac{1}{C_3 \cdot \log[(-1/C_2) - C_1]} \quad (8)$$

an equation which yields, for discretionarily chosen values of three of the coefficients:

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10 It is possible to link $C_4$ to the three first coefficients, $C_1$, $C_2$ and $C_3$, of the function.
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Figure 5. Optimism/pessimism context-dependent probability transformation function

The curve in figure 3 characterizes the collective mood of farmers.

Given that expectation, farmers decide at the end of t-1 to offer in period t a quantity $y_{a,t}$

$$y_{a,t} = \frac{1}{d} \cdot P_{a,t}$$

On the other hand, final demand at the end of period t will be directed by the (averaged) price resulting of the market interplay $P_{r,t}$. We may then write:

$$x_t = \frac{a - P_{r,t}}{b}$$

1.3.3. Natural risk impact

It is interesting to remark that historians relate heavily that dependence on climatic events since the early times where either data are available, but not after the late 1800s (Leroy-Ladurie, 2004, Vol. II). This suggests that natural risk, unlike economists have long continued to assert (Newbery and Stiglitz, 1981) may not be, in the present time, the bulk of the uncertainty faced by farmers or by investors on agricultural commodities.

Uncertainty isn’t any more of a solely exogenous type, but may be linked also to actors’ behavior. It has nowadays become of to a large part endogenous. This point is crucial. Of course, natural risk (not only climatic risk, but also diseases of plants or cattle, etc.) will impact the production they anticipate, $y_{a,t}$ The quantity $y_{a,t}$ they wish to produce at crop time will obviously be affected:

$$y_a = y_{a,t} \cdot \eta$$

The parameter $\eta$ stands for a specific realization of a random variable which will have to be specified according to past data. We may take a Normal distribution, but it certainly is only an approximation of the effective impacts of natural risk on crops. We shall take, in the simulations reported in the next section, values for natural risk which are rather close to the lower end. Of course, the distribution of natural risk is different for each zone of the world.

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11 As there is some time lag between retail sales and gross production, one might argue that dependence of the demand function from the previous campaign prices would rather be in order, at least in some cases.

12 This is a very stylized account of the phenomenon. For more on the impact of climate, see Maunder (1989).
Clearly, supply-demand gaps will frequently happen. We take them to equal involuntary variations of inventories. We thus have:

$$\Delta \text{Inv}_i = y_i - x_i$$  \hspace{1cm} (12)

It is expected that, the sum of these involuntary variations in inventories $\Delta \text{Inv}_i$ added to the initial inventory will remain non-negative in each of the five sectors over the whole simulation.

Considering (9) to (12), there is, in this model, what mathematicians call a fixed point, implying here $P_{a,t} = P_{r,t}$ and thus $\text{Inv}_i = 0$, which is given by $P = \frac{ad}{b+d} = PN$. This is the stationary “notional” equilibrium. It can be seen from (6) and from (9) to (12) that it implies a constant revenue at each period $t$, $R_t$, and thus a zero risk premium. No need then to anticipate next period’s price! Rational expectations are logically compelling in this limiting ‘dream case’. But it remains a dream. It certainly is not the sequence of agricultural evolution we are looking at here.

1.3.4. Short term investors, asymmetry of information between actors

We are considering here two different kinds of expectation formation schemes for short term investors. Some investors will simply infer that, if forward prices of the commodity under consideration increase above farmers’ expectation, they will be further increasing and therefore they should buy now to make money. Conversely, some other investors will tend to think that, if forward prices increase above farmers’ expectation as defined above (equations (5) to (8)), they will have to sooner or later return to a more “reasonable” level\textsuperscript{13}. We shall describe the first category as “naïve” and the second as “conservative”. Both categories produce “informational externalities”, attracting spot prices toward forward ones according to the scheme described below\textsuperscript{14}.

Assume short term investors take the gap

$$g_t = P_{a,t} - P_{r,t-1}$$  \hspace{1cm} (13)

as a useful guide to expectation formation by short term investors. Investors will then determine their long or short positions depending on the type of expectation scheme they adhere to. Investors’ determination of the prevailing tendency can, as a matter of fact, change all along the period, depending on the last evolutions of the markets prices. This evolution will determine how many investors are “naïve” and how many are “conservative”. If we denote by $BB_t$ the buying behavior (“going long”) at time $t$ of investors and by $w_i$ the relative “weight” of “naïve” behaviors – based on the idea that the change in price will continue in the same direction $\rightarrow$, total net increase in long positions (buying behavior) by investors in period $t$ may be represented by:

$$BB_t = \left[w_i B_i^N + (1-w_i) B_i^C \right] \frac{(m/i)}{t} \hspace{1cm} (14)$$

where positions by naïvely acting investors are given the exponent $N$ and positions by conservatively acting investors the exponent $C$. The symbol $i_t$ stands here for the basic interest rate of the most important money market in the corresponding economic zone. The

\textsuperscript{13} Note that we won’t distinguish here between the spot and the forward market, a distinction which would be of secondary importance for the purpose of this model, which is a medium term analysis.

\textsuperscript{14} In the oil industry, this attraction scheme is partly written in long-term contracts, where delivery prices are indexed on forward prices.
mass of speculators at some period \( t \) is the ratio between \( m \), and the level of \( i_t \), as it is reasonable to consider that \( i_t \) has an (inverse) influence on that “mass”. Long positions by naïve investors will be positively correlated to a rising price expectation, while the converse will be true for investors endowed with the conservative expectation formation scheme. Thus, taking linear behavior schedules with short profitability coefficients \( k^N \) and \( k^C \) respectively:

\[
B^N_t = k^N \cdot g_t, \quad B^C_t = -(k^C \cdot g_t)
\]  

with \( k^N \) and \( k^C > 0 \). Naïve investors tend to think that the present trend will continue, while conservative start to consider selling as soon as the gap \( g_t \) becomes positive.

It is common experience that the (Euclidean distance) absolute value of the gap \( ||g|| \) influences the determination of the relative weights of long and short positions: the larger \( ||g|| \), the smaller the relative weight of “naïve” behaviors simply extrapolating the tendency of prices, and conversely. Discrete choice models (Anderson, de Palma and Thisse, 1992) and other authors (Frankel and Froot, 1986, Kirman, 1991, Westerhoff, 2003) write that the relative weight of the naïvely acting investors depends on some power of the absolute value of some price gap, as can be justified from observation as well as on intuitive grounds\(^{15}\). We then write:

\[
w_t = \frac{1}{1 + |g|^j}
\]

With \( j=2 \), total net demand expressed by short term investors would then be, with \( i_t \) denoting the short term interest rate at time \( t \):

\[
\frac{m \cdot g_t(k^N - k^C |g_t|^2)}{i_t(1 + |g_t|^2)}
\]

we have however to take also into account the variation of inventories. The lower the inventories in terms of the yearly demand for a given commodity at the end of a given period, the larger the volatility of future spot prices of the next period (Deaton and Laroque, 1992; Routledge, Seppi and Spatt, 2000). From this larger volatility, we may predict that there will be a larger upward pressure of speculation on the pricing of the given commodity. Naïve investors will be acting more aggressively. Defining:

\[
\phi(\Delta Inv_{t-1}, x_{t-1}) = 1 + \Delta Inv_{t-1}/x_{t-1}
\]

We rewrite expression (17) to take that effect into account:

\[
\frac{m \cdot g_t[k^N / \phi(Inv_{t-1}, x_{t-1}) - k^C |g_t|^2]}{i_t(1 + |g_t|^2)}
\]

\(^{15}\) As an alternative interpretation, one could rely on the hypothesis that \( g=0 \) would yield insufficient reasons to every investor go long or short on the commodity considered, hence that the probability of either way would be \( .5 \). With the square of \( g \) positive, however, the probability of going long would outweigh the probability of going short and the difference could evolve, for reasons similar to the ones given above. A Normal law would determine that evolution on either side of the \( g=0 \) line. This interpretation would consider that everyone may go more or less long or short, instead of considering that there are two “polar” sorts of expectation with a proportion of investors on one side and the rest on the other side.
1.3.5. Resulting market price

The pressure on prices derives from (i) temporary excess supply (demand) of present year from producers over consumers’ final demand (ii) the pressure of investors net demand, which works as attracting spot prices. Indeed, whether they buy or sell, short term investors, by definition, will resell or buy back their contract at some point of time, for they fear nothing more than physical delivery. Thus, their net demand pressure has no mechanical, but an informational impact on the spot market.

The influence of farmers, Part (i) above, can be established from (9) to (12) and the value of their fixed point ($Inv_{t\rightarrow t}=0$), if we assume that there were no short term investors:

$$y_t = \frac{1}{d} P_{a,t} \eta_t \quad \text{and} \quad x_t = \frac{a - P_t}{b} \quad \text{while} \quad P_t = \frac{ad}{b + d}$$

One has then

$$P_t = -\frac{b}{d} P_{a,t} \eta_t + a \quad \text{while} \quad P_{t-1} = -\frac{b}{d} P_{t-1} + a$$

And finally:

$$P_{r,j} - P_{r,j-1} = -\frac{b}{d} (P_{a,t} \eta_t - P_{r,j-1})$$

We have to remember that Part (ii), the impact on the spot price of forward investors, has been written in terms of an equivalent to an over-demand. Equation (19) has then to be added with the opposite sign. This leads finally to the price dynamics equation:

$$E[P_{r,j} - P_{r,j-1}] = -\frac{b}{d} \frac{g_t}{E(\eta)} + \frac{m_g_i [k^N / \phi(Inv_{t\rightarrow t}, x_{t\rightarrow t}) - k^C |g_i|^2]}{\iota_i (1 + |g_i|^2)}$$

(20)

This view of agricultural commodity markets leads to a price dynamics in which parameters $b, d$ and $m$, considering $m$ as an exogenous factor, which can be kept constant for simulations purposes, will be determinant in the dynamics considered.

With the specification above, the story of price volatility is as follows: (i) natural risk, together with boundedly rational expectations, is the “match” which starts the fire, while (ii) the real bust of the brand comes from the short term investors behavior.

1.4. The central module

In our model, the central module takes care of the general interdependency of economic activity. As for the equations of the central module, they are relatively conventional in a computable general equilibrium (CGE) - model, though this central module is a world model and not only a one-country model where relations between a given country and the “rest of the world” would be examined\textsuperscript{16}. We limit therefore ourselves here, to save space, to a few comments on the role of the central module in Momagri’s approach\textsuperscript{17}. Although the module consists in a CGE- model, we insist on the fact that, even out of any interaction with the

\textsuperscript{16} There are many CGE models, but very few global models, encompassing the world economy: GTAP, LINKAGE, MIRAGE, and a couple of others (notably ID3) together with MOMAGRI.

\textsuperscript{17} On demand by e-mail (bertrand.munier@momagri.org or munier.iae@univ-paris1.fr), I shall be happy to send the mathematical framework of the central module.
risk module, it wouldn’t produce a state of (Walrasian) macroeconomic general equilibrium, for two reasons:

1) The model is not, strictly speaking, estimated, but only “calibrated”, i.e. it fits the data of the base year, 2001 for that matter. Nothing can be said about the equilibrium nature of the state of affairs in 2001. Hence, a strong qualification would have to be made if we were to claim that this central module leads to an equilibrium state (this is one of the limits of CGE models in general, though most authors do not care to mention it). At most, it can be regarded as an approximate Walrasian equilibrium state.

2) More importantly, the agricultural out of equilibrium prices from the risk module are introduced as constraints in a first run of the central module. And a second run of the central module, complemented by a run of the risk module, is required to produce a complete round of adjustment (see figure 3 above).

Compounding 1) and 2) above shows that our economic states, from one period to the other, are no Walrasian equilibria, but are economic states evolving (with possibly large a volatility) “around” such notional equilibria, illustrating Walras’ quote on top of this paper: the equilibrium is something “idealized”, “it never materializes”, but it plays a role akin to the one of an “attractor” in a complex system. Such a view is a much more faithful account of reality than what traditionally accepted models can yield. Some early simulations of the Momagri model give an idea of what this model can produce.

1.5. Some simulations stemming out from Momagri’s model

1.5.1. March 2008 Version 1

Figure 6. Simulations of March 2008. Momagri version 1. A scenario of full liberalization after 2009 under two different natural risk hypotheses. Index of annual average aggregate prices. 2001=100

The curves on this graph show annual averages of market prices of both cereals and animals. Hypotheses (1) refer, at world level and in each sector, to a small natural risk Hypotheses (2) refer, at world level and in each sector, to a higher level of natural risk. Impacts on prices are surprisingly low, although a few years only are being simulated. The conclusion is that a large part of volatility is endogenous. This finding has highly important policy implications.
It is interesting to note that, under this March 2008 simulation, attention was drawn on the possible fall during 2008 of natural productions prices, particularly of prices of cereals, while at the same period, standard models (and gurus) were all predicting stable or slightly increasing prices for wheat, etc.

1.5.2. March 2009 Version 2

Figure 7. Simulation of March 2009. Momagri version 2. Scenario of full liberalization in 2010. Average prices of cereals among the 10 regional zones of the world. Annual index 2001-2003= 100. Constant part of international trade, no monetary or exchange policy, low natural risk, weak and constant mass of short term investors

The results of this scenario can be somehow contrasted to the 2.5.1 results: volatility in weaker here until 2014, evolution does not follow exactly the same path as the one shown above.

These simulations should be taken as assessments of the impact of a complete liberalization on cereal prices. They are the results of a few draws in a larger set of possible results. However, these draws show similar evolutions. We simply take here the general tendency as an important element to be considered in international trade reform.

1.6. Some empirical data from OTC markets

From the specifications given to Momagri’s equations in version 1 (March 2008) as well as in version 2 (March 2009), the role of short term investors emerges as a leading one in explaining price volatility, together with monetary policy, more so than the traditional low elasticity of supply and demand curves. Do empirical data give support to this view? Figure 8 displays the spectacular rise of derivatives on over the counter (OTC) markets since 2004. Examining closely the type of underlying supports the hypothesis according to which agricultural commodities have been targeted by investors as substitutes to equities and real estate goods after the stock exchange slump of the early 2000. Such an explanation would suffer no outright rejection, to say the least.
The upward swing of the curve related to “other commodities” emerging in mid-2004 (the ‘outstanding amounts’ of the end-of-year originates in contracts decided earlier than at the end of 2004) is due to both oil and agricultural commodities. The swing in OTC derivatives with either one commodity as underlying represents a jump from 952 billion US Dollars in June 2004 to 12580 in June of 2008, a multiplication by a factor 12 or more. The index falls then back until December 08, where it takes a different course. It is interesting to note that the late spring of 2008 was also the peak of prices for several agricultural commodities, as well as for oil. It is difficult to deny that these markets are ‘financialized’ ones.

The next graph (figure 9) relates the said curve of outstanding derivatives taking as underlying either oil or agricultural commodities (left scale, in billions of US$) to prices of wheat and maize (in US$/ton, right scale). The link seems straightforward, though a correlation cannot be taken as final evidence.
More recently, in a widely circulated paper, Tang and Xiong show on more detailed data than ours that 2004 was a turning point for a number of issues:

1) The interconnection between financial and commodities markets. They show in particular that commodity index returns (in the sense recently defined by Gorton and Rouwenhorst in a seminal paper) are more exposed to variations in the world equity index than before.

2) The increased interdependence of these markets has induced a much larger volatility of commodity prices for a number of agricultural commodities studied (as well as for oil).

3) This last phenomenon can be mostly explained by the entrance of short term investors in indices. Indeed, commodities the prices of which enter the indices are more linked to such variations of the world equity index (as well as to oil price volatility) than before.

4) After 2004, the trading by index investors has made the trading volumes of individual commodities co-move more narrowly than before, and these changes in co-variations are larger for commodities within the index than for commodities not entering the indices.

The empirical evidence leads these authors to conclude that the large increase in commodity price volatility in 2008 has been definitely related to the presence of index investors. The latter have exerted what Jerome Stein once called “informational externalities”, i.e. they have changed the behavior of traditional participants to the markets involved as well as, consequently, the behavior of the said markets.

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18 They consider the GSCI (Goldman Sach commodity index) and the DJ-AIG (Dow Jones-AIG index) indices as well as price indices of given commodities.
2. Impacts and lessons for the future

The view presented above of agricultural commodity markets lead to revise a series of concepts or schemes of reasoning and call for adapted policy choices.

1) Volatility doesn’t result anymore, since the late 1800’s, from the sole natural uncertainty, but is an endogenously produced and lasting phenomenon. We certainly can try to limit it, by adjusting market structures and specifying regulatory and fiscal policies within some bounds, we never will eliminate it altogether. So, we certainly should give some tools to individual farmers to cope with some of uncertainty. Forward markets should be maintained and short term investors as well, to maintain liquidity. But these markets should be organized and OTC’s versions should be kept to a minimum or altogether banned. Insurance schemes should be considered, along th experience of some countries.

2) Most importantly, opening borders used to be a tool to decrease volatility in the XVIIIth Century, because uncertainty was then limited to an exogenous phenomenon, mainly linked to climate and other natural events, which are varying from one area to the other. Adding two statistically independent distributions yields a smaller variance and was a good way to decrease volatility. But opening international borders meant at that time having free markets for goods, not for factors of production (this was even the economic definition of a nation or of an integrated economic area). Today, factors move as well, but with very unequal speeds, capital being by far more mobile than labor - and labor than land, of course. We have forgotten about the lessons that Ragnar Nurkse wanted to remind us about in his “International Monetary Experience” Princeton leaflet. Opening borders means today heading also toward a completely free and deregulated short term capital movements world. This effect tends to increase volatility. In sum, the total effect of a full liberalization/opening of borders as understood today leads definitely to an increase in volatility, contrary to what many policy makers and/or politicians assert.

3) In particular, we should be wary about financial innovations, mostly based on the illusory belief of perfect information and rationality of agents, but paradoxically equipped with dangerous technical approximations (like the VaR, etc.) and leading economic agents to irrational beliefs like the ‘disappearance of risk’ when spread over to the market! We have experienced the consequences of such unregulated financial innovations. We are experiencing the same today when worrying about countries debts.

4) We should also change our way to assess welfare changes entailed by policies. Simply replacing equivalent monetary variations by expected equivalent monetary variations would be a mistake. For volatility also has an impact on the equivalent variations are computed, on one hand; and, on the other hand, volatility has an impact on investment and growth and on political instability, magnifying again this impact (Timmer 2002; Dawe 2001, 2010, Myers, 2006). Within a more limited volatility than today, the growth impact had been estimated between 0,5% and 1% yearly Domestic Income growth in developing countries, the bulk of it falling on producers rather than on consumers (Myers, 2006). Countries relying too much on resources from volatile commodities experience terms of trade volatilities which have a clearly adverse effect on investment and growth (Aghion et al., 2006). The question of choosing between stabilization and growth might be a biased question. Countries relying excessively on
commodity revenues to grow experience high costs in terms of welfare due to shifts in physical and human capital investment away from non-commodity based sectors when commodity prices are high may be difficult to reverse when these prices are low (Guriev et al., 2009). Diversification per se is welfare improving in this sense.

5) For similar reasons (in opposite directions), excess-dependence on commodities without real substitutes may be costly in terms of welfare. The optimal situation here depends highly on the level of international uncertainty, beyond price volatility. But it is important to note that there is also an aspect to food dependence strictly linked to efficiency and growth.

6) In this last perspective as well as to curb excessive speculation, a more reasonable inventory policy than pursued in the last twenty years should be restored. We know that volatility of prices is quite sensitive to inventory levels and variations (Deaton and Laroque, 1992, etc.). To further curb excess speculation, price limits and everything that decrease speculative leverage (compulsory guarantee deposits, taxation schemes, etc.) should be part of a consistent policy.
3. Concluding remarks: volatility everywhere

We thus have shown that volatility is a major aspect of commodity markets, more generally of financialized markets, and specifically of agriculture. The Momagri model does effectively integrate uncertainty and a dynamics of expectations, including short term investors, a dynamics which interacts with the state of the markets, at a world interconnection level. It is a modular and sequential model, which can be used policy wise for medium term issues. It can shed an important light on volatility and other important phenomena for about 10-20 years.

We also have now to worry about issues like climatic change and its impact on economic results and welfare, which pertain to the very long period (N. Stern, 2007). Traditional wisdom in this respect – based on the standard hypotheses evoked at the beginning of this paper- has been that the impact of volatility on economic results would decrease in the long run. Empirical research had confirmed the intuition on very long periods (200 years), calling upon the alleged phenomenon which economists call ‘mean reversion’ (around a trend, economic variables are bound to often return to the central tendency). J. Siegel has investigated the issue for the stocks market (....). But the world has changed: empirical economists tend today to lay the accent on the uncertainty about the trend itself, which finally leads to conclude that total resulting volatility in the long run increases. As we said in opening this paper, our world is a complex one and its trajectories follow each other in a way which is very difficult to predict. Unless we establish specific policies to limit it, volatility will become permanent.

The Momagri model is therefore an important tool of decision aid in agricultural policy. It can support simulations to evaluate price and income effects taking the volatility situation into consideration, which existing models hardly could do, for the reasons developed above. The model will therefore enable us to more thoroughly evaluate such or such scenario considered within the Doha negotiations.

Similarly, scenarios envisioned for the CAP will be more thoroughly appreciated to the extent that they can be evaluated within the volatility framework. The Momagri model provides Members of the European Parliament as well as officers in charge of elaborating the next CAP both a theoretical background and a simulation tool taking volatility effects into consideration.

Several features of the world deciphered by Momagri should be more particularly considered when redesigning the CAP, in particular (i) the increase of volatility entailed by a liberalization scheme, which would leave the way open to speculation, both in the short and in the long run (ii) the acute level which such an increase of volatility can reach in less developed countries experiencing hunger situations and massive rural migration to big cities (iii) the severe impact it also can have in Europe on some sectors suffering difficulties like milk or cereals (iv) the connection of volatility with food security already sketched above and all the costs precautions in this respect can help to avoid (v) the necessity to define some optimum in borders opening as explained above, in order to prevent every return to protectionism, which might trigger similarly negative - if not worse - effects.

Momagri, on the ground of the model presented above and beyond it, is elaborating a project of markets organization and regulation designed to contain the abovementioned impacts as well as the crises they might trigger. Such a policy should be pursued under
constant budgetary spending, which calls for designing renewed and modernized principles of government intervention. Such a project might be presented to European Institutions in the months to come.

It is crucial that the CAP to come be (i) adjusted to the specificity of the agricultural sector but also (ii) able to cope with present and future challenges in terms of price volatility limitation as well as (iii) with challenges offered by issues of natural and markets risk management.
References


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