Impacts of stockholdings behaviours on agricultural market volatility: a dynamic Computable General Equilibrium approach

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The successive CAP reforms question its price stabilizing aspect and more and more attention is being paid to private risk managing instruments such as storage. The effects of storage have already been widely studied in economic literature. But almost none of these studies do account of the links between producers', households' and stockholders' decisions as can a CGE model. Furthermore, the inter temporal decisions of these agents are generally not really taken into account when studying the effects of an instrument like storage allowing for inter temporal arbitrages. Finally, almost all of these studies focus on the effect of stockholdings on exogenous price volatility and assume rational expectations, which do not allow for the representation of the endogenous part, induced by market functioning, of risk; yet this endogenous risk has often been used to justify public intervention in agricultural markets. In this paper we build a model addressing these issues and conduct some illustrative simulations. Some of our results stand in contrast with the conclusions of previous economic studies concerning the effects of storage on market volatilities and reveal the importance of the role played by expectations of economic agents and by the links between their inter temporal decisions when studying such an instrument.

Key Words: Stockholding behaviours, General equilibrium, Endogenous risk, Inter temporal decisions

Introduction

One of the objectives of the European Common Agricultural Policy (CAP) when it was introduced was to ensure the stability of agricultural incomes in the European Union (EU). A system of public instruments was used to control the quantities of agricultural products supplied on European markets and thus to guarantee stable agricultural prices and incomes. Yet in 1992 the EU started to replace this price support scheme by a system of payments more decoupled from production and prices. This decoupling of farm payments was reinforced by the 2003 CAP reform and, as shown by the 2008 Health Check, is likely to be continued in the future. Yet, as shown notably by CHAVAS and KIM (2006), suppressing a price support program leads to increase price volatility.

The successive reforms of the CAP thus question its price stabilizing aspect. Some private instruments could however be used by European agricultural producers to manage their price risk but have not been extensively used until today, notably because of the existence of public instruments (ANDERSON, 1992). Private storage is one of these instruments. Indeed stockholding behaviours allow for inter temporal arbitrages (ANDERSON, 1992): when prices are low the demand for stocks is high and when prices rise the quantities stored are put back onto the market which comes to mitigate the rise. This mechanism was formerly used by the European Union to stabilize market prices through public stockholdings. In fact, as shown by LENCE and HAYES (2002), this public storage substituted speculative stockholdings. One can thus presume that private storage will be more and more used on European markets.

The effect of private storage on market dynamics is an important point and thus needs to be taken into account in economic evaluations of agricultural policies. Yet most of these economic evaluations are based on Computable General Equilibrium (CGE) models which rarely incorporate stockholding behaviours. However, in a market economy, prices result from several decisions of economic agents acting on several markets potentially linked between them; moreover, as pointed out by MAKKI et al. (1996), storage and trade can act complementarily on price volatility. Accounting for all these relationships, as can a CGE model do, thus seems crucial when one gets interested in the effects of storage on price risk. One of the reasons why CGE models do not include stockholdings behaviours is that most of them were not originally aimed at simulating short-run policy effects (Hertel et al., 2005), as a matter of fact, these models are generally not fully dynamic (FEMENIA and GOHIN, 2009). The purpose of this article is to tackle this issue by introducing stockholding behaviours in a dynamic CGE model able to account for agricultural price volatility.

Furthermore, the economic literature identifies two kinds of phenomenon explaining agricultural market prices volatility: this volatility can be due to exogenous random shocks like climatic hazards. But price fluctuations can also be endogenous, that is to say linked to market functioning and to expectation errors from economic agents. Indeed, in agricultural sectors there is a time lag between production decisions and harvests, this time lag implies that producers have to base their decisions on expected rather than on observed market prices, and their possible expectation errors can induce price fluctuations. This phenomenon was formalised by Ezekiel (1938) in his Cobweb theorem. Both of these two sources of volatility are linked in the sense that economic agents can sometime make mistakes because exogenous shocks occur between production decisions and harvests which generates price fluctuations and if they are not rational these fluctuations will spread over time. Whereas the impacts of stockholdings behaviours on exogenous price volatility have been quite largely studied in the economic literature (WILLIAMS and WRIGHT, 1991, DEATON and LAROQUE, 1992), the studies dealing with their effects on endogenous volatility are much rarer. Though, non rational speculative behaviours of private stockholders can be said to destabilize markets (see RAVALLION, 1987 for instance). In fact we have not been able to find more than one paper addressing the issue of the modelling of stockholding behaviours in an imperfect expectation

framework (MITRA and BOUSSARD, 2009). Furthermore none of the aforementioned works are conducted in a general equilibrium framework.
The model we build in this article has several characteristics allowing the integration of these different elements. First, we depart from a widely used general equilibrium framework: the GTAP model and database (HERTEL, 1997). Then, we rely on the work of FEMENIA and GOHIN (2009) to build a dynamic model taking inter temporal decisions of economic agents into account. These inter temporal decisions are based on imperfect expectations which enables a representation of the endogenous aspect of market volatility, the exogenous part being introduced *via* exogenous shocks. Finally, private stockholding behaviours are introduced into the model. In addition to be conducted in a general equilibrium, our work essentially differentiates from the previous work dealing with storage and endogenous volatility by the specification of the inter temporal behaviours of all economic agents and by the timing of stockholders' decisions; those are taken once harvests are put on markets and not contemporarily to production decisions as in MITRA and BOUSSARD (2008).
Once we build this model, we run some simulations to study the effects of European wheat storage when exogenous productivity shocks occur in the Rest of the World. These simulations reveal that considering imperfect expectations and accounting for the general equilibrium links between sectors and for the inter temporal dimension of the decisions of economic agents can lead to results different from what is commonly found in the economic literature, notably those concerning the transmission of market fluctuations between sectors/ regions or from prices to production quantities. Furthermore, our results tend to confirm that the high autocorrelations observed between agricultural prices can be attributed to stockholdings behaviours, which previous studies (DEATON and LAROQUE, 1992) had suspected but had not been able to reproduce.
The remaining of the article is organised as follows: in the next part we describe the characteristics of the model, namely its dynamic characteristics, the way market price volatility is introduced, how private stockholdings behaviours are modelled and finally the execution of the model; a second part of the article is devoted to the results of the simulations we have conducted and to some sensitivity analysis of these results; finally we conclude.

1. The model

Most of the CGE models used today to assess the effects of agricultural policies are not adapted to deal with price volatility and, *a fortiori*, with the effects of stockholdings on this volatility, because they are mostly static, do not open the possibility to represent the endogenous aspect of price volatility and do not introduce stockholding behaviours. To tackle this issue we build a model able to account for the dynamic evolution of markets and for the inter temporal decisions of economic agents. This model is also suited to the representation of exogenous and endogenous price volatility and includes stockholdings behaviours.
Our starting point is a version of the widely used GTAP framework (HERTEL, 1997) adapted to the study of agricultural markets: the GTAP AGR framework. The main differences between this model and ours are described in what follows.

1.1 Characteristics of dynamic behaviours

The first concern when dealing with price fluctuations is to model market evolution period by period, that is why we rely on the work of FEMENIA and GOHIN (2009) who build a dynamic CGE model based on the GTAP framework.
In this model sectoral capital stocks accrue from one period to another in each region:

$K_{irt+1} = (1-\delta_{ir})K_{irt} + I_{irt}$, with K the capital stock, I the new investment and δ the depreciation rate of capital, the subsets i, r and t denoting respectively the sector, the region and the time period concerned.
New investments at one period will thus increase capital stocks for the next period. Capital stocks increase as time goes by as long as sectoral investments are higher than the depreciation of capital stock. When investments equal capital depreciation, capital stocks stop increasing and then remain constant; this first steady state period will be referred to as period T.
Using capital accumulation as a link between periods is quite a usual way to introduce dynamics in CGE modelling (see for instance the Linkage model from the World Bank or the Mirage model from the CEPII). However most of the existing dynamic CGE models do not account for inter temporal decision processes of economic agents and are thus not able to account for the formation of their expectations. As in FEMENIA and GOHIN (2009), this drawback is overcome in our model: investment decisions of producers and saving decisions of households are based on inter temporal arbitrages.
Indeed, to take his investment decision the producer seeks to maximize the present value of his firm (DEVARAJAN and GO, 1996), which corresponds to the discounted value of all his expected future profits (capital income) minus his expected future investment costs:

$$\begin{cases} \max \ \pi_{ir} = \sum_t \frac{1}{(1+r)^t}\left(wk_{irt}K_{irt} - \left(1+\frac{\varphi}{2}PI_{irt}\frac{I_{irt}^2}{K_{irt}}\right)PI_{irt}I_{irt} \right) \\ st \quad K_{irt+1} - K_{irt} = -\delta_{ir}K_{irt} + I_{irt} \end{cases}$$

With r the interest rate, wk the capital income, PI the price of investment and φ an adjustment parameter: the term $\frac{\varphi}{2}PI_{irt}\frac{I_{irt}^2}{K_{irt}}$ represents the adjustment cost of capital (MCKIBBIN and WILCOXEN, 1998).
Solving this optimisation problem leads to a condition determining optimal investment in our CGE model:

$$wk_{irt+1} + (1-\delta_{ir})PI_{irt+1}\left(\varphi\frac{I_{irt+1}}{K_{irt+1}}+1\right) = (1+r)PI_{irt}\left(\varphi\frac{I_{irt}}{K_{irt}}+1\right) - \frac{\varphi}{2}PI_{rt+1}\frac{I_{irt+1}^2}{K_{irt+1}^2}$$

As in steady state investment equals capital depreciation and prices are stable, from period T this equation becomes: $wk_{rT} = PI_{rT}(\delta_{ir}+r) + PI_{rT}\varphi\delta_{ir}\left(\frac{\delta_{ir}}{2}+r\right)$

Households also base their saving decisions on an inter temporal trade-off. Indeed they spend a part of the income they earn at one period to consume goods, which brings them some utility, and save the remaining part. The part of the income saved at one period will be used later to consume and represents a future utility. So, the representative household in each region seeks to maximize the value of its inter temporal utility, subject to an inter temporal budget constraint:

$$\begin{cases} \max \ U_{rt} = \sum_t \frac{1}{(1+\rho)^t}u(Q_{rt}) \\ st \ \sum_t \frac{E_{rt}}{(1+r)^t} \geq \sum_t \frac{1}{(1+r)^t}(P_{rt}Q_{rt} + S_{rt}) \end{cases}$$

With ρ a time preference parameter (households have a preference for immediate utility), Q the quantity consumed, P the composite consumer price, E the total income (including interest earned from foreign assets, factor returns, distributed profits and tax receipts) and S

savings. The first order condition of this program allows to determine the evolution of savings:

$E_{rt} - S_{rt} = \left(\frac{1+\delta}{1+r}\right) \; E_{rt+1} - S_{rt+1}$. The aforementioned equation, combined with the fact that in a steady state savings equal investment, allows to derive the levels of savings for all periods.

These, combined with a foreign debt accumulation period by period, are the main characteristics which enable our model to reproduce the dynamic evolution of markets.

1.2 Modelling of the market prices volatility

Two sources of price volatility on agricultural markets are identified in economic literature (BUTAULT and LE MOUËL, 2004): price fluctuations can be due to exogenous stochastic shocks and can also be generated by non rational market behaviours. These two aspects are introduced in our model. The first part of this section is devoted to the introduction of exogenous disturbances in the model and the second one to the modelling of non rational behaviours.

1.2.1 Introduction of exogenous stochastic disturbances in the model

Many economists have argued that fluctuations on agricultural markets were essentially due to demand and supply shocks (MOSCHINI and HENNESSY, 2001). Indeed, the time lag between production decisions of farmers and their harvests induces a short-term rigidity of the agricultural supply, which can hardly adjust to market price changes. Furthermore most agricultural products are staples and demand for these goods is quite inelastic. Because of these two characteristics agricultural markets are very sensitive to market shocks: a supply decrease due to a climatic hazard for instance will result in a large price increase. This phenomenon is formalized by the King's law. Yet agricultural production is exposed to several epidemic and climatic risks and these exogenous shocks occur quite frequently, thus generating price fluctuations.

Our purpose here is to introduce random supply shocks in the dynamic model to incorporate exogenous price fluctuations.

In our model the agricultural technology is represented by a nested CES production function. The first nest combines production factors to create value added; the second one combines the aggregate factors with intermediate consumptions to produce output:

$$\begin{cases} VA_{irt} = \gamma_{ir} \;\; a_{ir} K_{irt}^{\;\rho_{ir}} + b_{ir} L_{irt}^{\;\rho_{ir}} + c_{ir} T_{irt}^{\;\rho_{ir}} \;\; ^{\frac{1}{\rho_{ir}}} \\ Y_{irt} = \Phi_{ir} \;\; \beta_{ir} VA_{irt}^{\;\theta_{ir}} + \; 1-\beta_{ir} \;\; IC_{irt}^{\;\theta_{ir}} \;\; ^{\frac{1}{\theta_{ir}}} \end{cases}$$

With VA the value added, L the labour factor, T the land factor, Y the quantity produced and IC the aggregate intermediate consumption. a, b, c and β are share parameters, ρ and θ determine respectively the degree of substitutability between capital, labour and land and between value added and intermediate consumption, finally γ and φ are productivity parameters.

Supply shocks are introduced in our model through the productivity parameter Φ. Indeed we assume that these shocks can be linked to productivity shocks.

We thus introduce random disturbances ε such that $\Phi shock_{ir} = \Phi_{ir} \;\; 1+\varepsilon$ with $\Phi schock_{ir}$ the "shocked" productivity parameter and assume that $\varepsilon \sim N \;\; 0, \sigma^2_{\varepsilon}$ which implies that

$\Phi shock_{ir}$ fluctuates around Φ_{ir} with a variance equal to $\sigma^2{}_{\Phi shock_{ir}} = \Phi^2{}_{ir}\,\sigma^2{}_{\varepsilon}$, that is to say that the Φ_{ir} values calibrated from the GTAP database correspond to average expected values over many years.

1.2.2 Introduction of imperfect expectations

The inter temporal dimension of decision processes in our model imply that agents have to form expectations about the future path of economy at the time decisions are made. Many studies dealing with uncertainty assume rational expectations (WRIGHT, 2001, WILLIAMS and WRIGHT,1991, PRATT and BLAKE, 2007), which means that that economic agents have the same knowledge as economists about markets functioning and that expected prices are those corresponding to the economic model (MUTH, 1961). However, according to some authors, expectations of economic agents are not rational in the Muth sense (BOUSSARD, 1996, ROSSER and KRAMER, 2001), due to the costs generated by the acquisition of information. As formalized by Ezekiel (1938) in his famous Cobweb theorem the non rationality of farmers can cause expectation errors to spread over time and induce endogenous fluctuations of market prices. This endogenous price volatility has besides often been used to justify public interventions in agricultural markets (BOUSSARD, 2006).

Assuming that farmers have the right information concerning their own productivity (that they know the distribution of the exogenous shocks affecting their production) seems quite obvious. On the other hand, we consider that their expectations about market prices are non rational and hence incorporate endogenous volatility into our model.

As pointed out by NEWBERY and STIGLITZ (1981), if some farmers have imperfect expectations, the existence of private stockholdings behaviours can induce serial correlation and make past prices informative. So, even if exogenous productivity shocks are independent over time the use of past information to form expectations about the future is justified in our case. For that purpose we rely on NERLOVE's work (1958) who proposed a formalisation for adaptive expectations based on past information. These Nerlovian expectations are such that agents take their past errors into account to form their new expectations: $\hat{P}_t = \hat{P}_{t-1} + \alpha\left[P_{t-1} - \hat{P}_{t-1}\right] = \alpha P_{t-1} + (1-\alpha)\hat{P}_{t-1}$, $\hat{P}$ denoting expected prices and P observed market prices, $0 < \alpha \leq 1$ can be seen as a measure of the adjustment speed of expectations. In fact the lower α, the slower expectations adjust to market changes. An extreme case of Nerlovian expectation arises when α equals 1: the economic agent only considers the previous period to form his expectation. These are called naïve expectations.

1.3 Introduction of stockholding behaviours

We focus now on the introduction of stockholdings behaviours in our dynamic CGE model. We distinguish private speculative stockholdings which are held by private stockholders seeking to make profit from price changes and public stockholdings only aimed at stabilizing market prices. To account for stockholdings it is first necessary to represent the behaviours of private stockholders, the first part of this section is devoted to this issue. Then in a third part we explain how a new storage sector is introduced into the model. Finally we discuss the other elements that have to be introduced into the model to account for stockholdings.

1.3.1 Determination of stockholdings behaviours

A new agent, the stockholder, is introduced into the model. There is one representative stockholder in each region.
This agent holds stocks, can sell a part of these stocks or buy other stocks at current market price at each period.
Let ST be the quantity stored and k the unitary storage cost in the region.
Let A be the quantity bought and V the quantity sold by the stockholder. These bought and sold quantities affect the stocks:
$ST_{irt} = ST_{irt-1} + A_{irt} - V_{irt}$ or $ST_{irt} = ST_{irt-1} + \Delta_{irt}$ with $\Delta_{irt} = A_{irt} - V_{irt}$
The stockholder seeks to maximize his inter temporal profit which corresponds to the discounted sum of his sales minus his purchases and the storage costs. His program can thus be expressed as:

$$\max \sum_t \frac{1}{1+r}^t \sum_i \ \hat{P}_{irt} \ V_{irt} - A_{irt} \ - k_{rt} ST_{irt} \quad \text{or} \quad \max \sum_t \frac{1}{1+r}^t \sum_i \ -\hat{P}_{irt}\Delta_{irt} - k_{rt} ST_{irt}$$

$$s/t \quad ST_{irt} = ST_{irt-1} + A_{irt} - V_{irt} \qquad\qquad s/t \quad ST_{irt} = ST_{irt-1} + \Delta_{irt}$$

The Lagrangian associated to this program is:

$$L = \sum_t \frac{1}{1+r}^t \sum_i \ -\hat{P}_{irt}\Delta_{irt} - k_{rt} ST_{irt} \ - \sum_t \sum_i \lambda_{irt} \ ST_{irt} - ST_{irt-1} - \Delta_{irt}$$

Solving the optimisation program thus leads to the following first order conditions:

$$\frac{\partial L}{\partial \Delta_{irt}} = 0, \forall t \Leftrightarrow -\frac{\hat{P}_{irt}}{1+r}^t + \lambda_{irt} = 0 \Leftrightarrow \lambda_{irt} = \frac{\hat{P}_{irt}}{1+r}^t, \forall i, r, t$$

$$\frac{\partial L}{\partial ST_{irt}} = 0, \forall t \Leftrightarrow -\frac{k_{rt}}{1+r}^t = \lambda_{irt} - \lambda_{irt+1}$$

$$\Rightarrow \boxed{P_{irt} + k_{rt} = \frac{\hat{P}_{irt+1}}{1+r}}$$

We find here the standard relationship explaining stockholding behaviours (Williams and Wright, 1991): if the cost of buying goods at time t and storing them during one period is less than the (discounted) price at which these goods can be sold at time t+1 ($P_{irt} + k_{rt} < \frac{\hat{P}_{irt+1}}{1+r}$), then stockholders will buy goods thus increasing the current prices until $P_{irt} + k_{rt} = \frac{\hat{P}_{irt+1}}{1+r}$.

On the contrary, if $P_{irt} + k_{rt} > \frac{\hat{P}_{irt+1}}{1+r}$ then stockholders will sell their stocks thus lowering current market prices until $P_{irt} + k_{rt} = \frac{\hat{P}_{irt+1}}{1+r}$ or until their stocks are null in which case the market is in equilibrium even if $P_{irt} + k_{rt} > \frac{\hat{P}_{irt+1}}{1+r}$. These considerations allow us to explain why stockholding behaviours come to mitigate market price volatility.
We thus have the complementarity problem:

$$ST_{irt} \geq 0$$

$$P_{irt} + k_{rt} \geq \frac{\hat{P}_{irt+1}}{1+r}$$

$$ST_{irt}\left(P_{irt} + k_{rt} - \frac{\hat{P}_{irt+1}}{1+r}\right) = 0$$

The stockholding behaviour will thus be in the model as: $P_{irt} + k_{rt} \geq \frac{\hat{P}_{irt+1}}{1+r} \quad \perp ST_{irt}$, as we assume non rational expectations $\hat{P}_{irt+1}$ is such as $\hat{P}_{t+1} = \alpha P_t + (1-\alpha)\hat{P}_t$, because we assume that, contrary to producers and like households, stockholders face market prices at time they take their decisions. Here our work differentiates from MITRA and BOUSSARD (2008), who also assume that stockholders form imperfect expectations, indeed in their work, storage is assumed to occur at the time production decisions are taken and not once harvests are put on the market.

1.3.2 Creation of a storage service sector

Storing a commodity generates costs paid by private or public stockholders and made up, for instance, of the rent of grain silos and of the wages of workers who carry out stock handling. In order to determine these factor incomes we introduce a storage service sector in our model. This sector uses labour and capital factors which are combined through a Constant Elasticity of Substitution (CES) function to produce the service good.

The optimisation problem of producers in this sector can thus be written as:

$$\begin{cases} \min \ wl_{STrt}L_{STrt} + wk_{STrt}K_{STrt} \\ st \ Y_{STrt} = \chi_r \left(d_r K_{STrt}^{\frac{\varpi_r - 1}{\varpi_r}} + (1-d_r) L_{STrt}^{\frac{\varpi_r - 1}{\varpi_r}} \right)^{\frac{\varpi_r}{\varpi_r - 1}} \\ st \ Y_{STrt} = \sum_i ST_{irt} \\ st \ K_{STrt} = (1-\delta_{iST}) K_{STrt-1} + I_{STrt} \end{cases},$$

with Y_{STrt} the supply of storage service, L_{STrt} and K_{STrt} the quantities of labour and capital, wl_{STrt} and wk_{STrt} their unitary income, d a share parameter, χ a productivity parameter and ϖ the elasticity of substitution between labour and capital.

Solving this program leads to the zero profit condition: $P_{STrt}\sum_i ST_{irt} = wl_{STrt}L_{STrt} + wk_{STrt}K_{STrt}$, which s equation will allow us to determine the unitary storage costs $k_{rt} = P_{STrt}$.

Furthermore, as the capital stock in this sector, as in other sector, is subject to adjustment costs, storage capacity at one period is limited even if no storage bound is explicitly imposed.

The specification of this storage service sector differentiates our work from Hertel at al. (2003) who also incorporate stockholdings in a CGE model but consider that storage is costless and fix and exogenous storage capacity limit.

1.3.3 Equilibrium conditions

To take stockholding into account in our CGE model some conditions insuring markets equilibrium have to be modified.
First, supply and demand of goods for storage modify the equilibrium market prices. So, the market equilibrium conditions determining market prices now includes beginning-of-period stocks on the supply side and end-of-period stocks on the demand side.
Then, as in HERTEL et al. (2005), in our model private stockholdings are considered as a form of investment and are thus financed by savings. This comes to modify the equation ensuring the equality between investments and savings at world level and determining the world interest rate[1].
So, when stockholdings are introduced in the model, equation $Y_{irt} + M_{irt} = Q_{irt} \quad \perp P_{irt}$ becomes $Y_{irt} + M_{irt} + ST_{irt} = Q_{irt} + ST_{irt-1} \quad \perp P_{irt}$, and equation $\sum_r S_t = \sum_r \sum_i PI_{irt} I_{irt} \quad \perp r$ becomes $\sum_r S_t = \sum_r \sum_i PI_{irt} I_{irt} + \sum_r \sum_i P_{irt} \Delta ST_{irt} + \sum_r k_{rt} \sum_i ST_{irt} \quad \perp r$, with Y_{irt} the quantity of good i produced in region r at time t, M_{irt} net imports and Q_{irt} the quantity consumed in region r.

1.4 Execution of the model

Our dynamic model is solved period by period and in two steps for each period. This sequencing of the model resolution deserves some explanation.
As we already mentioned, consumers and producers base their decisions on expected future market prices. If a productivity shock occurs at, say, the first period, after agricultural producers have decided how much to produce base on their expectations about the future, then the effective realized output quantities won't be the same as the ones farmers had expect. On the other hand the other economic agents observe market conditions and thus know the "shocked" market prices at time they take their decisions. Thereby the aforementioned dynamic model has to be solved in two steps: in a first step the model is solved with a productivity value equal to $E \ \Phi shock_{ir} \ = \Phi_{ir}$, the outcome corresponds to what agricultural producers plan for the future period and thus provides the level of factors they will use to produce; then in a second step the model is solved with the shocked productivity but this time the levels of factors used are set equal to those determined in the first step and are thus exogenous; the agricultural supply is then determined by the production function, the outcome of the model corresponds to what effectively happens on markets, at least for the first period.
In the second period, the first step is re-executed taking into account the new levels of stockholdings and capital stocks which result from the first period and the new expectations of agricultural producers, and the second step is re-executed taking into account the new value of the random productivity parameter. And so on.
This sequencing of the model resolution allows us to account for the time lag existing between production decisions and harvests in agricultural sectors.

2. Simulations and results

The main purpose of this article is to build a fully dynamic general equilibrium model aimed at assessing the effects of stockholding behaviours on agricultural prices volatility and able to

[1] See Femenia and Gohin, 2009 for more information on closure rules and on the necessity of introducing this endogenous interest rate in the case of imperfect expectations

account for the endogenous dimension of this volatility. Having described the structure of this model in the first part, this second part is devoted to the results of some simulations which are conducted as an illustrative purpose, in order to have a first insight of the impacts of the model specifications on the simulated effects of stockholdings behaviours on market volatility.

2.1 Definition of simulations

In these simulations we focus on the European wheat sector, which is assumed to be the only sector producing a storable commodity, and study the impacts on this sector of stochastic supply shocks arising in other regions of the world during 25 periods. Assuming that stockholdings only concern one sector and one region in the world is obviously unrealistic, but we recall that these simulations are conducted as an illustrative purpose; this assumption is made in order to better identify the different simulated effects and so to ease the interpretation of the results.

2.1.1 Data

We use the 6th version of the GTAP database which contains data corresponding to the year 2001 as a benchmark.

Data are aggregated in 27 sectors, among which 21 are agricultural sectors, and in 3 regions: the European Union (EU), the United States (US) and the Rest of the World (RoW).

As mentioned in part 1, we add a new sector producing storage services.

As the GTAP database was initially aimed at being used in a static framework we need to make some assumption to calibrate the data for our dynamic model: we assume that the initial interest rate r, the time preference parameter ρ and the unit capital installation cost φ are all equal to 5%. Then, as in Femenia and Gohin (2009), we assume that the initial point is a steady state. This assumption, which facilitates the calibration of the other dynamic parameters, implies that prices are stable and, in fact, that private stockholdings are null. However, the CES form of the production function in the storage service sector does not allow for null production. To overcome this issue we also assume that some precautionary wheat stocks, representing 10% of wheat production, are held by the public sector in the European Union. These precautionary stocks are constant over time and thus have no effect on price volatility.

Finally, in the standard case, the expectation adjustment parameter α is set to 1/10, and the elasticity of substitution between production factors in the storage service sector ϖ is set to 0.8. We conduct some sensitivity analysis to these parameters, the results of which are presented in the last part of this section.

2.1.2 Characteristics of markets volatility

The price volatility in our models results from production shocks occurring in the Rest of World's wheat sector. These shocks can lead agricultural producers to make mistakes when they anticipate forthcoming prices.

A first step in our simulations is thus to generate the shocks affecting the productivity parameter $\Phi_{wheat,RoW}$. The value of $\Phi_{wheat,RoW}$ calibrated from the GTAP database, and corresponding as we have seen to the mean value of the random parameter $\Phi shock_{wheat,RoW}$, is 1.95.

We recall that $\Phi shock_{wheat,RoW} = \Phi_{wheat,RoW}(1+\varepsilon)$, with $\varepsilon \sim N(0,\sigma^2_{\varepsilon})$.

Calibrating the value of σ^2_{ε} is not a trivial task. Indeed, the data available, like those from the Food and Agriculture Organization (FAO) that have been used by Hertel et al. (2003) to characterize the exogenous production volatility in there model, concern the production quantities or yield, but these data result in fact from producers' decisions, among others, and not only from exogenous shocks. So, as we will see later, the volatility of quantities produced can be much higher than the volatility of productivity shocks, especially when market agents are assumed to have imperfect expectations. For these reasons, in our 'standard' case we set the value of σ^2_{ε} to 0.9% an then conduct some sensitivity analysis of the results to this value.

The 25 stochastic exogenous shocks are thus generated according to a normal distribution $N(0, 0.9\%)$. They are plotted on Figure 1 and Table 1 represents the main characteristics of their distribution.

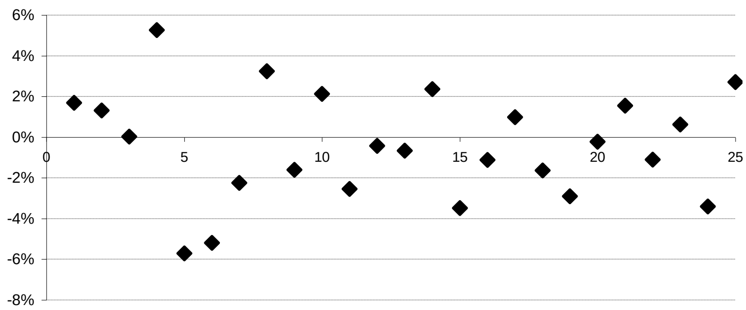

Figure 1- Productivity shocks

Table 1 below reports the main characteristics of the 25 productivity shocks generated according to the above mentioned distribution.

Mean	S. D. [a]	First-order a-c[b]
-0.4 %	2.7 %	-0.18

Table 1-Distribution characteristics of productivity shocks

[a] Standard Deviation, [b] Autocorrelation

2.1.3 Benchmark results

Before focusing on the impacts of stockholding behaviours, some attention must be paid to the outcome of our dynamic CGE model before the introduction of storage. These results will be used as a benchmark to assess the effects of private storage.

The evolutions of wheat output in the three regions of the world are represented on figure 2 and the evolutions of wheat price are represented on figure 3.

The first thing to note is that, even if exogenous productivity shocks occur in the RoW only, the wheat production fluctuates in the same way in the EU and, to a lesser extent, in the US. The same phenomenon arises for prices: price fluctuations are synchronous. Besides, as illustrated in table 2, wheat prices in all regions are highly correlated. This synchronism is of course partly due to trade exchanges between regions, but, while if agents were rational this trade could allow a dampening in market fluctuations at world level *via* a risk sharing mechanism, in case of imperfect expectation market fluctuations synchronise and are amplified at world level. This illustrates one important criticism against agricultural trade liberalisation (Boussard et al., 2005).

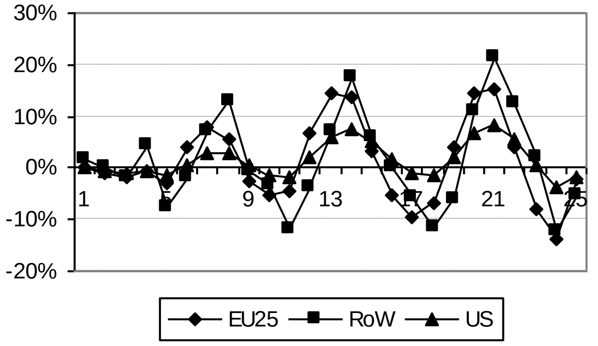

Figure 2- Wheat output (% change compared to the baseline)

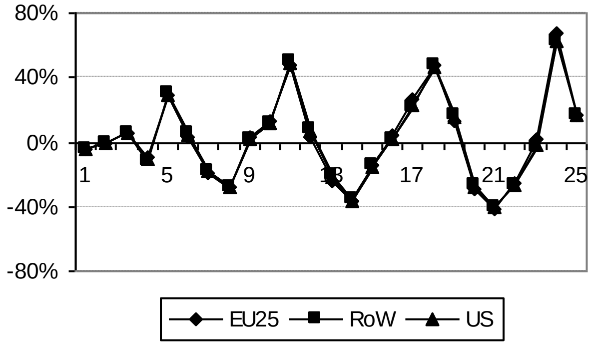

Figure 3- Wheat price (% change compared to the baseline)

	EU	RoW	US
EU	1	0.996	0.997
RoW	0.996	1	1
US	0.997	1	1

Table 2 - Correlation between wheat prices

Then, productivity shocks are comprised between -6% and +6% (see figure 1) but output fluctuations are much more important: a production increase of more than 20% is observed in the RoW in period 20 and a nearly 15% decrease arises in the EU in period 23, as shown on figure 2. The mechanisms explaining these market evolutions are as follows. If at one period a negative productivity shock at has occurred in the RoW, leading to wheat price and capital income in wheat sector to increase, at the next period wheat agricultural producers re-adjust their price expectation according to the previously observed price increase: they expect market price higher than the initial price, and so plan to produce more. Then, if a positive productivity occurs leading the harvest to be even larger than that which producers had expected, the wheat market price decreases. At the same time the increase of capital income observed during the previous period leads producers to expect an increase of capital income for the forthcoming periods and so to make new investments which will lead to an increase in their capital for the third period. This increase of capital stock can lead producers to not decrease their production as much as they should if they expect a price decrease for the future. So the market volatility originating from exogenous productivity shocks is amplified by the linked imperfect price and factor return expectations, and this endogenous aspect can even generate sudden price peaks as in periods 5, 11, 18 and 24 (see figure 3). Indeed, these periods follow periods where positive shock occur (see figure 1), so wheat producers expect a market price decrease, this price expectation, combined with the fact that investments in previous period were small and that their capital stock has just decreased, leads them to plan to produce less than initially. Because of a negative productivity shock, the realized harvest is actually much lower than initially see figure 2). As wheat demand is quite price inelastic, this large decrease of production induces a very large price increase. Following these peaks, producers re adjust their expectations and market prices recover lower levels for the next periods.

In the EU and the US realized producers' output are equal to what they plan but, as market prices are affected by those of the RoW, this does not prevent them from making expectation errors leading to endogenous price fluctuations.

These results illustrate the relative importance of endogenous compared to exogenous market fluctuations. Indeed, as shown by in table 3, exogenous productivity shocks in the RoW wheat sector characterized by a 2.7% standard deviation can generate output fluctuations characterized by a standard deviation 3 times higher. This comes to illustrate the difficulty to calibrate the distribution of productivity shocks based on production data. The standard deviations around 26% for wheat are in accordance with the fluctuations observed on figure 3.

		Output changes		Price changes		
		Mean	S. D.	Mean	S. D.	First-order a-c
Wheat	EU	1.19%	7.74%	2.05%	26.77%	0.03
	RoW	1.31%	8.82%	2.07%	26.13%	0.03
	US	1.53%	3.27%	1.77%	25.99%	0.03
Oilseeds	EU	-0.05%	0.97%	0.64%	4.59%	0
	RoW	-0.13%	0.85%	0.61%	4.37%	0
	US	-0.07%	0.48%	0.63%	4.48%	0
Other Cereals	EU	-0.05%	0.82%	0.39%	3.14%	0
	RoW	-0.18%	1.32%	0.62%	4.59%	0
	US	-0.07%	0.45%	0.45%	3.33%	0

Table 3 - Distribution characteristics of output and price changes compared to the initial values

Table 3 also shows that other sectors related to wheat are also impacted in all regions: as the wheat production is at the mean higher than its initial value, the oilseeds and other cereals productions are lower at the mean which leads to some mean prices increases. The standard deviations of output and prices in these sectors are not negligible, even if not as high as in the wheat sector. So exogenous productivity shocks arising in the RoW wheat sector spread to all regions and to several sectors, generating market fluctuations amplified by the non rationality of market participants. As a matter of fact regional incomes are also impacted by these shocks even if they occur in only one region, one sector: the standard deviation of regional income change is equal to 0.08% in the EU, 0.11% in the RoW and 0.12% in the US (see Table 6).

2.2 Impact of stockholdings

Having described the outcome of the model without storage, we now rely on the impacts of stockholding behaviours concerning the European wheat sector on the results.

2.2.1 Standard case

In what we call our standard case, we set the historical weighting parameter α to $1/10$ for all agents and the substitution elasticity between labour and capital in the storage service sector is set to 0.8. Some sensitivity analysis of the results to these parameters, as well as to the volatility of production shocks, will be presented in the next parts.
Figures 4 and 5 below represent the fluctuations of wheat output and price when stockholdings behaviours are introduced in the model.
We can notice on Figure 4 that output fluctuations in the wheat sector seem to be slightly smoothed compared to the case without stocks for all regions, but the most interesting result appears on Figure 5: the European wheat price is not synchronized with RoW's and US's ones now. This is also reflected in the correlation between prices reported in Table 4: whereas wheat prices in the RoW and in the US are still highly correlated, the correlations between wheat price in the EU and prices in other regions are reduced by about 25%. Stockholdings behaviours tend in fact to "disconnect" the European wheat market from world markets.

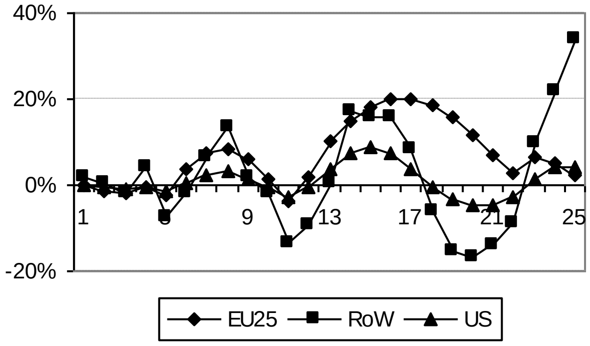

Figure 4 - Wheat output (% change compared to the baseline)

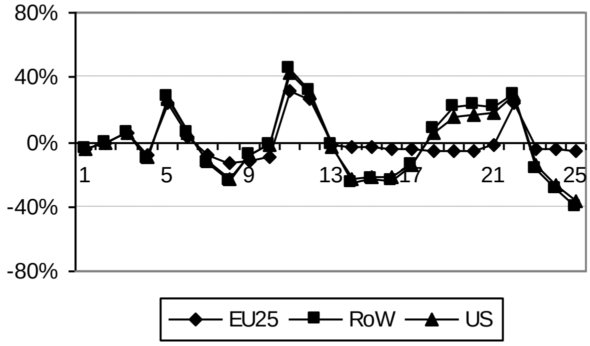

Figure 5 - Wheat price (% change compared to the baseline)

	EU	RoW	US
EU	1	0.715	0.758
RoW	0.715	1	0.998
US	0.758	0.998	1

Table 4 - Correlation between wheat prices

We can also see on Figure 5 that price decreases in the European wheat sectors are very limited but do not totally disappear. They are in fact bounded by the expectations of stockholders concerning the future wheat price and the storage costs. Indeed, let us recall that if stockholders expect a price rise, they buy wheat until: $P_{irt} + k_{rt} = \frac{\hat{P}_{irt+1}}{1+r}$, which prevents the wheat price to decrease below $\frac{\hat{P}_{irt+1}}{1+r} - k_{rt}$. On the other hand, we can still observe some price peaks in the EU as in other regions, these peaks however lower than before the introduction of storage, which can this time be attributed to stock outs as illustrated by Figure 6.

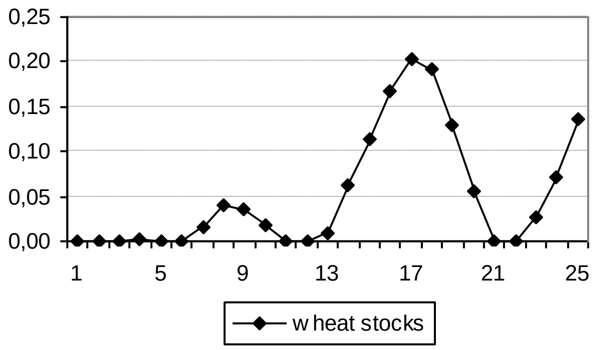

Figure 6 - Wheat stocks in the EU (in millions of tonnes)

Private stockholdings behaviours thus seem to limit the occurrence of price peaks due to the effect of large production shocks on the non rational behaviours of producers, while inducing other peaks due to stock outs.

The distribution characteristics of output and price changes in the wheat, oilseeds and other cereals sectors are reported in table 5.

		Output changes		Price changes		
		Mean	S. D.	Mean	S. D.	First-order a-c
Wheat	EU	6.80%	7.27%	0.44%	12.28%	0.075
	RoW	2.18%	12.46%	-0.73%	21.89%	0.599
	US	1.01%	3.59%	-1.08%	19.98%	0.471
Oilseeds	EU	-0.48%	1.00%	0.51%	3.29%	0.017
	RoW	-0.07%	0.79%	0.24%	2.95%	0.013
	US	-0.02%	0.44%	0.26%	3.02%	0.013
Other Cereals	EU	-0.25%	0.69%	0.40%	2.04%	0.006
	RoW	-0.09%	1.19%	0.18%	3.08%	0.014
	US	-0.05%	0.40%	0.14%	2.11%	0.006

Table 5 - Distribution characteristics of output and price changes

A first thing to note is that, compared to the distributions observed before the introduction of storage in the model (Table 3), prices are now lower at the mean in all regions and all sectors. This result stands in contrast with the idea, found in several studies, that price stabilization would not change mean price. In fact, as pointed out by WILLIAMS and WRIGHT (1991), as long as the mean price is endogenous and the responses and feedbacks of economic agents are taken into account, a stabilization mechanism cannot keep this price unchanged. Our results come to illustrate their point. In our simulation framework, the mean price decrease is furthermore accentuated by the limitation of the huge sudden price increases due to non rational expectations when storage is not allowed. Then, the effects of stockholding behaviours commonly found in the economic literature are that storage tends to stabilize price and destabilize production (WILLIAMS and WRIGHT, 1991).While our results suggest that stockholdings behaviours effectively limit price fluctuations, particularly in the European wheat sector, output fluctuations are not systematically increased: they increase in the US and RoW wheat sectors and in the EU oilseeds sectors but decrease in all other sectors presented in the table. One explanation for the decrease of output fluctuations is that the stabilization of price also allows producers to stabilize their expectations and so to stabilize their production. So, even if stockholding behaviours can play a destabilizing role as advocated in the economic literature, they also induce an improvement of other agents' expectations and the two phenomenons interact. Moreover, as pointed out by Newbery and Stiglitz (1981), agricultural producers are more concerned with the stability of their income than with price or production stability. Here our results suggest, as presented in Table 6, that the introduction of storage allows to stabilize farmers' incomes in all cases, even when their production is destabilized.

	Without stockholdings			With stockholdings		
	Wheat	Oilseeds	Other Cereals	Wheat	Oilseeds	Other Cereals
EU	16.97%	2.10%	2.00%	13.02%	1.40%	1.28%
RoW	41.30%	2.47%	6.79%	32.04%	1.64%	4.42%
US	17.11%	1.90%	3.78%	12.29%	1.26%	2.34%

Table 6 - Standard deviation of farm income changes

A last point that differs in our results from what is found in the economic literature is that decrease of price volatility induced by stockholdings behaviours is shared by all regions, even if more important in the EU; this differs from the view expressed by TYERS and ANDERSON (1992) for instance of a risk sharing between regions. Here stockholders allow all market agents to improve their expectation and thus decrease the endogenous part of price volatility.

Finally, according to DEATON and LAROQUE (1992) the high first order autocorrelation observed on agricultural prices could be due to stockholdings behaviours. However these authors have not been able to reproduce this autocorrelation with their storage model assuming rational expectations. MITRA and BOUSSARD (2009) who assume imperfect expectations have neither been able to reproduce this feature of agricultural prices distribution. None of these studies rely on a general equilibrium model. Yet, as shown by Tables 3 and 5, in our dynamic CGE framework the introduction stockholdings leads the first order autocorrelation of wheat prices to be multiplied by at least 20 in the wheat sectors and to also increase in the other sectors. The inter temporal dynamic dimension of our model thus allows to take into account the link between period induced by stockholders behaviours.

2.2.2 Sensitivity Analysis

The simulations presented above suggest that modelling the effect of stockholdings behaviours in a dynamic inter temporal CGE framework assuming non rational expectations can lead to results on market risks quite different from those commonly found in the economic literature. Indeed, these results suggest that storage effectively allows to stabilize prices and induces a destabilization of income, but it does not necessarily destabilize output. Furthermore, in our results there is no evidence of a transmission of price volatility from the sector concerned with stockholdings to other sectors or regions. However to run these simulations some parameters determining the variability of exogenous shocks, the form of stockholders' expectations and the elasticity of storage service supply, have been set to arbitrary values. Some sensitivity analyses are now conducted to test the sensitivity of our results to these values.

Sensitivity to the variability of supply shocks

In our standard case the supply shocks implemented in the RoW wheat sector are generated according to a normal distribution with a standard deviation σ_ε equal to 3%.

We now run other simulations for different values of σ_ε, namely 1%, 2%, 4% and 5%.

We have reported in Table 7 below the changes in standard deviation of outputs, prices and incomes induced by the introduction of storage for the different volatilities of exogenous shocks.

Regarding these results, it appears that the volatility of productivity shocks has a huge influence on the effects of storage on price volatility. Indeed, when the shocks are highly volatile ($\sigma_\varepsilon = 4\%$ and $\sigma_\varepsilon = 5\%$), stockholdings behaviours tend to stabilize wheat, oilseeds and other cereals prices in all regions, as in our standard case, whereas when they are less volatile ($\sigma_\varepsilon = 1\%$ and $\sigma_\varepsilon = 2\%$), price volatilities increase with the introduction of storage.

On the other hand, in all cases price volatilities increase or decrease simultaneously in all sectors: there is no kind of price risk transfer. We can also see from these results that a destabilization of prices induces a destabilization of output, which is due to the destabilization of agents' expectations, but the contrary is not necessarily true: even when stockholdings behaviours reduce price risk, they do not necessarily stabilize output. However, farm income is stabilized in all cases.

			$\sigma_\varepsilon = 1\%$	$\sigma_\varepsilon = 2\%$	$\sigma_\varepsilon = 4\%$	$\sigma_\varepsilon = 5\%$
Prices S.D.	Wheat	EU	2.6%	5.7%	-45.2%	-65.9%
		RoW	3.9%	15.1%	-14.3%	-40.9%
		US	3.8%	13.2%	-20.2%	-45.9%
	Oilseeds	EU	0.0%	7.8%	-36.7%	-52.9%
		RoW	1.9%	12.6%	-32.8%	-56.0%
		US	0.0%	11.6%	-36.8%	-55.7%
	Other Cereals	EU	0.9%	11.0%	-29.3%	-50.4%
		RoW	0.9%	10.3%	-32.7%	-52.9%
		US	0.9%	10.6%	-33.3%	-52.4%
Output S.D.	Wheat	EU	8.4%	18.4%	-32.2%	16.4%
		RoW	6.0%	10.3%	16.5%	-34.7%
		US	9.8%	4.2%	-20.0%	-37.1%
	Oilseeds	EU	4.8%	28.6%	1.6%	-45.9%
		RoW	3.0%	21.2%	-11.8%	-52.2%
		US	0.0%	25.0%	-10.8%	-48.0%
	Other Cereals	EU	3.7%	23.1%	18.8%	-13.5%
		RoW	4.5%	17.4%	-9.7%	-48.6%
		US	0.0%	14.3%	-10.0%	-41.7%
Income S.D.	Wheat	EU	-1.43%	-1.13%	-1.61%	-1.10%
		RoW	-1.82%	-1.90%	-1.98%	-1.99%
		US	-1.43%	-1.61%	-2.10%	-2.07%
	Oilseeds	EU	-2.04%	-2.02%	-2.08%	-1.84%
		RoW	-2.05%	-2.05%	-2.06%	-2.04%
		US	-2.05%	-2.04%	-2.06%	-2.08%
	Other Cereals	EU	-1.92%	-1.70%	-2.09%	-2.08%
		RoW	-2.05%	-2.06%	-2.04%	-2.02%
		US	-2.02%	-2.00%	-2.06%	-2.07%

Table 7 – Changes in Standard Deviations induced by the introduction of storage in the model

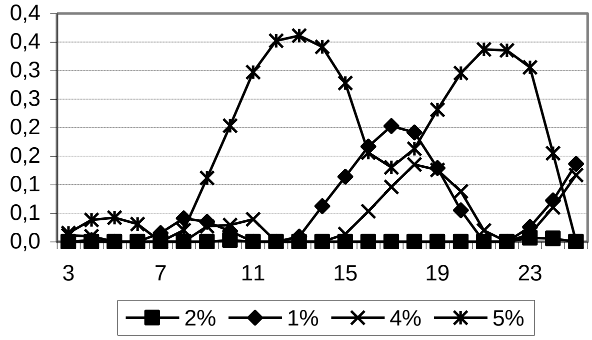

Figure 7 - Wheat stocks in the EU (in millions of tonnes)

Sensitivity to the expectations of stockholders

In our standard case we consider that stockholders form their expectations in the same way than the other agents in the model: the historical weighting parameter α is set to 1/10 for all of them. However, as shown by CHAVAS (1999), expectations of economic agents are heterogeneous, and one can presume that speculative stockholders may have expectations different from other agents. We investigate here the impacts of different stockholders' expectation schemes on the volatility of markets. We thus run some simulations considering different values for the historical weighting parameter α, namely 1/3, 1/5,1/30 and 1/50. The changes in standard deviations of prices, outputs and incomes induced by stockholdings behaviours are reported in Table 8.

A first thing to note is that in all cases here the introduction of storage allows to stabilize prices in all regions, and that the lowest α is, that is to say the more past information is taken into account by stockholders, the more the price volatility is reduced by the introduction of storage in the model. Output fluctuations are also dampened when α decreases, even if we can still not conclude whether stockholdings behaviours tend to increase output variability or not. As for $\alpha = 1/10$, the volatility of farm income decreases for $\alpha = 1/30$ and $\alpha = 1/50$ in all regions with the introduction of storage in the EU. However, for $\alpha = 1/3$ and $\alpha = 1/5$, that is to say when stockholders react more quickly than other agents to price news, or said in another way, when they take less account of past information than other agents, stockholding behaviours in the EU wheat sector tend to increase the volatility of farm income in that sector, but not in other sectors. These results come to confirm what FEMENIA and GOHIN (2009) pointed out in their paper on the role of expectation schemes: the dynamic of markets is smoothed when agents slowly react to price news.

			$\alpha = 1/3$	$\alpha = 1/5$	$\alpha = 1/30$	$\alpha = 1/50$
Prices S.D.	Wheat	EU	-34.6%	-48.0%	-54.1%	-55.1%
		RoW	-14.5%	-19.4%	-16.2%	-14.1%
		US	-21.0%	-26.1%	-23.1%	-20.9%
	Oilseeds	EU	-24.2%	-29.9%	-35.0%	-36.9%
		RoW	-24.2%	-27.2%	-32.9%	-33.1%
		US	-26.4%	-30.3%	-36.6%	-38.1%
	Other Cereals	EU	-20.5%	-23.7%	-28.3%	-29.4%
		RoW	-23.6%	-27.0%	-32.5%	-33.6%
		US	-23.4%	-27.0%	-32.6%	-33.7%
Output S.D.	Wheat	EU	127.4%	60.7%	-24.4%	-25.3%
		RoW	41.2%	28.8%	44.2%	46.4%
		US	40.1%	17.1%	8.6%	9.5%
	Oilseeds	EU	-11.0%	-15.9%	-15.9%	-15.9%
		RoW	-6.1%	-6.8%	-9.1%	-8.3%
		US	-2.2%	-4.4%	-11.1%	-11.1%
	Other Cereals	EU	3.1%	2.1%	1.0%	1.0%
		RoW	-2.4%	-3.5%	-5.9%	-5.9%
		US	-2.1%	-4.2%	-8.3%	-8.3%
Income S.D.	Wheat	EU	46.93%	24.89%	-57.09%	-53.84%
		RoW	-29.51%	-38.23%	-24.15%	-21.08%
		US	-22.95%	-36.10%	-37.42%	-34.45%
	Oilseeds	EU	-33.30%	-40.32%	-51.36%	-51.09%
		RoW	-32.05%	-38.99%	-53.97%	-54.10%
		US	-31.88%	-38.88%	-53.37%	-53.49%
	Other Cereals	EU	-13.80%	-38.94%	-61.88%	-61.35%
		RoW	-34.48%	-40.57%	-55.27%	-55.09%
		US	-39.24%	-47.62%	-65.24%	-65.26%

Table 8 - Changes in Standard Deviations induced by the introduction of storage in the model

Sensitivity to the elasticity of storage supply

In this last analysis we focus on the sensitivity of our results to the elasticity of the storage supply. Indeed, the storage service sector, labour and capital are used to allow the storage of physical quantities. These factors are combined through a CES production function characterized by a substitution elasticity between factors ϖ. A change in ϖ thus induces a change in the supply elasticity of the storage service. In our standard framework, ϖ is set to 0.8, which is quite high. One could argue that storage resources, like silos for instance, do not adjust so easily. That is why we run some simulations for lower values of ϖ, namely 0.4 and 0.7 in order to test the sensitivity of our result to the elasticity of storage supply. Table 9 reports the changes in standard deviations of prices, outputs and income for these different simulation settings.

As one could expect the highest ϖ is, that is to say the more easily storage supply can adjust to stockholders demand, the more stockholdings behaviours allow to stabilize prices and outputs. However, as previously we find here that in all cases the introduction of storage in the model leads to stabilize prices and farm incomes in all sectors and all regions, and that it does not necessarily destabilize output. The main conclusions we can draw from our model about the effects of stockholdings behaviours on market risk thus seem robust to the level of storage supply elasticity.

			$\varpi = 0.4$	$\varpi = 0.7$
Prices S.D.	Wheat	EU	-48.0%	-54.1%
		RoW	-19.4%	-16.2%
		US	-26.1%	-23.1%
	Oilseeds	EU	-29.9%	-35.0%
		RoW	-27.2%	-32.9%
		US	-30.3%	-36.6%
	Other Cereals	EU	-23.7%	-28.3%
		RoW	-27.0%	-32.5%
		US	-27.0%	-32.6%
Output S.D.	Wheat	EU	69.4%	64.7%
		RoW	16.9%	27.2%
		US	0.3%	10.7%
	Oilseeds	EU	81.7%	151.2%
		RoW	-3.8%	2.3%
		US	-15.6%	-13.3%
	Other Cereals	EU	176.3%	269.1%
		RoW	-4.7%	0.0%
		US	-18.8%	-16.7%
Income S.D.	Wheat	EU	-1.38%	-1.36%
		RoW	-2.11%	-2.11%
		US	-1.93%	-1.95%
	Oilseeds	EU	-1.92%	-1.76%
		RoW	-2.07%	-2.09%
		US	-2.01%	-2.02%
	Other Cereals	EU	-2.06%	-1.92%
		RoW	-2.09%	-2.10%
		US	-2.03%	-2.04%

Table 9 - Changes in Standard Deviations induced by the introduction of storage in the model

Conclusion

The successive reforms of the CAP question its price stabilizing aspect and more and more attention is paid to private risk managing instrument such as storage. The effects of private storage on market volatility have already been widely studied in economic literature. But almost none of these previous studies do account for the links between producers', households' and stockholders' decisions as can a CGE model do. Furthermore, the inter temporal decisions of these agents are generally not really taken into account which is a drawback when studying the effects of an instrument like storage allowing for inter temporal arbitrages. Finally, almost all of these studies focus on the effect of stockholdings on exogenous price volatility and assume rational expectations, which does not allow for the representation of the endogenous, induced by market functioning, part of risk; yet speculative

stockholders have sometimes been blamed to increase the volatility on agricultural markets because of their non rational behaviours.
To address these issues we build a dynamic CGE model, taking the inter temporal decisions of economic agents into account, including imperfect expectations and private stockholding behaviours and then conduct some simulations.
These simulations reveal some interesting results, which, even if they do not completely contradict the outcome of previous studies, come to mitigate them. Whereas several studies conclude that stabilization schemes preserve mean prices, in our framework this is not the case: the expectation improving role of stockholdings behaviours tend to limit the occurrence and magnitude of sudden price peaks due accumulation of expectation errors from other agents; price peaks still exist under storage but they are mostly due to stock outs phenomenons, and this tend to decrease market prices at the mean.
Concerning the effects of private stockholding behaviours on market volatility, which is a central issue in the current debates on agricultural market risks, we find, like MITRA and BOUSSARD (2009) that stockholding behaviours can in fact have a destabilizing effect on prices when exogenous shocks are small but their effect becomes stabilizing for bigger shocks; and in that case their price stabilizing effect is all the more important stockholders take much past information into account to form their expectations. Then, some studies like WILLIAMS AND WRIGHT (1991), for instance, argue that if stockholding behaviours stabilize prices, they also destabilize production; this is not necessarily the case in our framework: when stabilizing prices, stockholdings behaviours also stabilize producers' expectations and production. In the same way, the improvement of expectations allows to stabilize market prices in other sectors than the sector of the storable commodity (wheat in our simulations), there is no transfer of volatility between regions or between sectors. Furthermore, we find that, stockholdings behaviours in the EU tend to stabilize income in each region, except if stockholders take less account of past information than other agents to form their expectations.
In addition to these refinements bring to the study of the effects of stockholdings behaviours on market volatility, our framework allows to overcome some shortcomings of existing studies. Indeed, because of the inter temporal dynamic dimension of our CGE model, we find here evidence of the serial correlation of prices induced by stockholdings behaviours, advocated by NEWBERY and STIGLITZ (1981), that previous studies like those of DEATON and LAROQUE (1992), assuming rational expectations, or MITRA and BOUSSARD (2009), assuming imperfect expectations, could not reproduce. Furthermore, our results reveal the difficulty to estimate a distribution of exogenous (for instance climatic) production shocks based on production data, especially if market agents are not fully rational, because these data already result from many decisions based on agents' expectations.
Finally, we must acknowledge that the simulations presented here are just conducted as an illustrative purpose: the storage takes place in the EU wheat sector only and the productivity shocks concern wheat in the rest of the world only, furthermore we have not taken into account the risk aversion of economic agents which can have an impact on their decisions. Further work should be done to overcome these limitations and build a CGE model aimed at studying the effect of commodity price stabilisation program, which as pointed out by several authors (NEWBERY and STIGLITZ, 1983, WILLIAMS and WRIGHT, 1991, WEAVER and HELMBERGER, 1977) should not be not without accounting for storage activities.

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