Impacts of Stockholding Behaviour on Agricultural Market Volatility: A Dynamic Computable General Equilibrium Approach

Wirkungen von Lagerhaltung auf die Volatilität der Agrarmärkte: Analysen mit einem allgemeinen Gleichgewichtsmodell

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Abstract

Successive CAP reforms raise the question of whether it can have a price-stabilizing capability. In this context 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 the economic literature. But hardly any of these studies take account of the links between producers', households' and stockholders' intertemporal decisions and, in particular, they do not use a dynamic CGE model. Furthermore, a large number of previous studies focus on the effect of stockholding on price volatility due to exogenous shocks and assume rational expectations. It is more the endogenous aspect of risk, induced by expectation errors, that has often been used to justify public intervention in agricultural markets. In this paper we construct a model addressing these issues and we conduct some illustrative simulations. Some of our results are at variance with the conclusions of previous economic studies concerning the effects of speculative storage on market volatilities. We also reveal the vital role played by the form of economic agents' expectations and by the links between the intertemporal decisions of market participants.

Key words

stockholding behaviour; general equilibrium; endogenous risk; intertemporal decisions

Zusammenfassung

Nach den verschiedenen Reformen der Gemeinsamen Agrarpolitik stellt sich zunehmend die Frage, ob von dieser Politik noch eine preisstabilisierende Funktion ausgehen kann. Zunehmende Bedeutung wird daher privaten Risikomanagementstrategien beigemessen, insbesondere der privaten Lagerhaltung. In der ökonomischen Literatur sind Wirkungen der Lagerhaltung bereits ausführlich untersucht worden. Allerdings ist den Beziehungen zwischen den intertemporalen Entscheidungen von Produzenten, Haushalten und Lagerhaltern kaum nachgegangen worden, insbesondere nicht im Rahmen eines dynamischen allgemeinen Gleichgewichtsmodells. Überdies hat sich die Mehrzahl vorhandener Studien auf den Effekt der Lagerhaltung auf die Preisvolatilität konzentriert, die von exogenen Produktionsschwankungen ausgehen, und es wurde vollkommene Voraussicht unterstellt. Endogene Produktionsschwankungen, die auf fehlerhafte Preiserwartungsbildung zurückgehen, sind aber häufig zur Begründung staatlicher Eingriffe auf Agrarmärkten herangezogen worden. Dieser Beitrag greift diesen Aspekt endogenen Risikos auf. Es wird ein allgemeines Gleichgewichtsmodell formuliert unter Berücksichtigung von privater Lagerhaltung und fehlerhafter Preiserwartungsbildung der Produzenten, und ausgewählte Modellsimulationen werden vorgestellt. Die Ergebnisse zeigen, dass mehrere bisherige Erkenntnisse zu den Effekten privater Lagerhaltung auf die Volatilität von Agrarmärkten zu revidieren sind. Die Form der Erwartungsbildung ist entscheidend für die ermittelten Wirkungen privater Lagerhaltung und auch die Tatsache, wie die intertemporalen Entscheidungen der Marktteilnehmer miteinander verbunden sind.

Schlüsselwörter

Lagerhaltungsverhalten; allgemeines Gleichgewichtsmodell; endogenes Marktrisiko; intertemporale Entscheidungen; Marktvolatilität

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. 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 revealed notably by CHAVAS and KIM (2006), abolishing a price-support program leads to increasing price volatility.

Thus, the successive reforms of the CAP lead us to question its price-stabilizing role. Some private instruments could, however, be used by European agricultural producers to manage their price risk but they have not so far been extensively used, principally because of the existence of public instruments (ANDERSON, 1992). Private storage is one of these instruments. Indeed, stockholding behaviour allows for intertemporal arbitrage (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 mitigates the rise. This mechanism was formerly used by the European Union to stabilize market prices through public stockholdings. In fact, this public storage substituted speculative stockholdings (LENCE and HAYES, 2002). One can thus presume that private storage will be used more and more on European markets, which raises the question of its effect on agricultural market volatility. One does indeed wonder if, and if so to what extent, the use of storage will make it possible to mitigate the increase of market volatility induced by the evolution of the CAP.

The economic literature identifies two kinds of phenomenon explaining the volatility of agricultural market prices: volatility can be due to exogenous random shocks like climatic hazards and 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 stockhold-ing behaviour on exogenous price volatility have been quite widely 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, even though non-rational speculative behaviour of private stockholders is sometimes said to destabilize markets (see RAVALLION, 1987 for instance). In fact, we have not been able to find more than one paper that addresses the issue of modelling stockholding behaviour in an imperfect expectation framework (MITRA and BOUSSARD, 2008).

Furthermore, none of the aforementioned works are conducted in a general equilibrium framework, typically because existing Computable General Equilibrium (CGE) models do not incorporate stockholding behaviour. However, the impacts of market stabilization may be borne by different economic agents, like producers and consumers, and are not limited to the regions and sectors directly concerned by the stabilization scheme (NEWBERY and STIGLITZ, 1981). Moreover, in a market economy, prices result from several decisions taken by economic agents acting on several markets that are potentially linked. So the decisions of several agents, including stockholders, can in fact influence producers' or consumers' expectations if these expectations are not perfect but based on past information only. Taking account of all these relationships, as a CGE model can, becomes crucial when one focuses on the effects of storage on price risk. One of the reasons why CGE models do not include stockholding behaviour 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 behaviour in a dynamic CGE model able to take account of agricultural price volatility.

The model we construct here has several characteristics that allow 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 create a dynamic model that takes intertemporal decisions of economic agents into account. These intertemporal decisions are based on imperfect expectations, which enables us to represent the endogenous aspect of market volatility, the exogenous part being introduced *via* exogenous shocks. Finally, private stockholding behaviour is introduced into the model. In addition to being conducted in a general equilibrium, our work differs essentially from the previous work dealing with storage and endogenous volatility by specifying the intertemporal behaviour of all economic agents and by the timing of stockholders' decisions – taken once harvests are put on markets and not simultaneously with production decisions as in MITRA and BOUSSARD (2008).

Once we have constructed 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 taking account of the general equilibrium links between sectors and the intertemporal dimension of the decisions of economic agents can lead to results different from what is commonly found in the economic literature, notably those findings concerning the transmission of market fluctuations between sectors/regions or from prices to production quantities. The remainder 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 stockholding behaviour is modelled, and finally the execution of the model. The second part of the article is devoted to the results of the simulations we have conducted and to some sensitivity analyses of these results. These are followed by our conclusions.

1 The Model

As pointed out by NEWBERY and STIGLITZ (1981), it is worth considering the potential impacts of stockholding behaviour on price volatility in a general equilibrium framework. Indeed, the costs of price instability arising in one sector or one region are not limited to this sector or region, because this instability can be spread over the whole economy. Price stabilization can thus be beneficial to different economic agents in different regions. In this case, stockholders are not isolated and their decisions can influence those of producers and consumers, and *vice versa*. However, most of the CGE models used today to assess the effects of agricultural policies are not adapted to dealing with price volatility and, *a fortiori*, with the effects of stockholdings on this volatility, because they are mostly static, are not able to represent the endogenous aspect of price volatility and do not introduce stockholding behaviour. To tackle this issue we create a model capable of taking into account the dynamic evolution of markets and the intertemporal decisions of economic agents. This model is also suited to representing exogenous and endogenous price volatility and includes stockholding behaviour.

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 the following.

1.1 Characteristics of Dynamic Behaviour

The first concern when dealing with price fluctuations is to model market evolution period by period. This is the reason for relying the work of FEMENIA and GOHIN (2009) who construct 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.

Using capital accumulation as a link between periods is quite a common way of introducing 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 take account of intertemporal decision processes of economic agents and are thus not able to consider 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 intertemporal arbitrage.

Indeed, to take his investment decision the producer seeks to maximize the present value of his firm (DEVARAJAN and GO, 1998), which corresponds to the discounted value of all his expected future profits (capital income) minus his expected future investment costs:

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

With r the interest rate, wk the capital income, PI the price of investment and φ an adjustment parameter: the term $\frac{\varphi}{2}\frac{I_{irt}}{K_{irt}}$ represents the adjustment cost of capital (MCKIBBIN and WILCOXEN, 1999).

Solving this optimisation problem leads to a condition determining optimal investment in our CGE model:

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

As we will detail later, because in our model producers have limited knowledge about the output price, capital returns and the interest rate in the distant future, we then assume that they consider that, at some date, their investments will equal their capital depreciation. It means that they expect the economy to reach a steady state from this period. Indeed, this producers' steady-state condition may never appear, because they periodically revise their plans, but this formulation defines the current optimal investment plan for firms, including current investment.

Households also base their saving decisions on an intertemporal trade-off: they spend a part of the income they earn in one period to consume goods, which brings them some utility, and save the remaining part. The part of the income saved in 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 intertemporal utility, subject to an intertemporal 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 us to determine the evolution of savings:

$$(2)\quad E_{rt} - S_{rt} = \left(\frac{1+\delta}{1+r}\right)(E_{rt+1} - S_{rt+1}).$$

Like producers, households have limited knowledge about prices and income in the distant future; we thus also assume that they consider that the economy will reach a steady state where regional savings equal regional investment at some date. Once again, the steady state expected by households may never be reached but this condition, combined with equation (2) enables us to derive saving plans of households and thus current savings.

These different characteristics of agents' intertemporal decisions, combined with a foreign-debt accumulation period by period, are the main features of our model that facilitate the simulation of the dynamic evolution of markets.

1.2 Modelling of the Volatility of Market Prices

Two sources of price volatility on agricultural markets are identified in the 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 behaviour. 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 part to the modelling of non-rational behaviour.

1.2.1 Introduction of Exogenous Stochastic Disturbances in the Model

Many economists have argued that fluctuations on agricultural markets are 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 agricultural supply that 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 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, agricultural technology is represented by a nested CES production function. The first nest combines production factors to create value added;

the second combines the aggregate factors with intermediate consumption to produce output:

$$(3) \quad \begin{cases} VA_{irt} = \gamma_{ir}\left(a_{ir}K_{irt}{}^{\rho_{ir}} + b_{ir}L_{irt}{}^{\rho_{ir}} + c_{ir}T_{irt}{}^{\rho_{ir}}\right)^{\frac{1}{\rho_{ir}}} \\ Y_{irt} = \Phi_{ir}\left(\beta_{ir}VA_{irt}{}^{\theta_{ir}} + (1-\beta_{ir})IC_{irt}{}^{\theta_{ir}}\right)^{\frac{1}{\theta_{ir}}} \end{cases}$$

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. We assume that these shocks can be linked to productivity shocks.

We thus introduce random disturbances ε such as $\Phi shock_{ir} = \Phi_{ir}(1+\varepsilon)$, with $\Phi shock_{ir}$ 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 intertemporal dimension of decision processes in our model implies that agents have to form expectations about the future path of the 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 economic agents have the same knowledge as economists about the functioning of markets and that expected prices are those corresponding to the economic model (MUTH, 1961). However, processing and collecting information can be costly and it can in fact be more rational for economic agents to form imperfect expectations (JUST and RAUSSER, 2002) and, as formalized by EZEKIEL (1938) in his famous Cobweb theorem, the non-rationality of farmers can cause expectation errors to spread over time and to induce endogenous fluctuations of market prices. This endogenous price volatility has often been used to justify public interventions in agricultural markets (BOUSSARD et al., 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, private stockholding behaviour 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 the work of NERLOVE (1958) who proposed a formalisation for adaptive expectations based on past information. These Nerlovian expectations are such that agents take their past expectation errors into account to form their new expectations:

$$(4) \quad \hat{P}_{t+1} = \hat{P}_t + \alpha\left[P_t - \hat{P}_t\right] = \alpha P_t + (1-\alpha)\hat{P}_t .$$

$\hat{P}$ denotes expected prices and P observed market prices, $0 < \alpha \le 1$ 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 current period to form his expectation for the future. These are called naïve expectations.

1.3 Introduction of Stockholding Behaviour

We focus now on the introduction of stockholding behaviour in our dynamic CGE model. We distinguish between 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 take account of storage, it is first necessary to represent the behaviour of private stockholders, and the first part of this section is devoted to this issue. Then in the 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 take account of stockholdings.

1.3.1 Determination of Stockholding Behaviour

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 can buy other stocks at the current market price in each period. Let ST be the quantity stored and k the unitary storage cost in the region. A is the quantity bought and V the quantity sold by the stockholder. These bought and sold quantities affect the stocks:

(5) $ST_{irt} = ST_{irt-1} + A_{irt} - V_{irt}$ or $ST_{irt} = ST_{irt-1} + \Delta_{irt}$ with $\Delta_{irt} = A_{irt} - V_{irt}$

The stockholder seeks to maximize his intertemporal profit which corresponds to the discounted sum of his sales minus his purchases and the storage costs. His program can thus be expressed as:

$$\max \sum_t \frac{1}{(1+r)^t} \sum_i \left(\hat{P}_{irt} \Delta_{irt} - k_{rt} ST_{irt} \right)$$
$$s|t \quad ST_{irt} = ST_{irt-1} + \Delta_{irt}$$

Solving this optimisation program leads to the conditions:

(6) $$P_{irt} + k_{rt} = \frac{\hat{P}_{irt+1}}{(1+r)}$$

We find here the standard relationship explaining stockholding behaviour (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 nil, 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 behaviour is able to mitigate market price volatility.

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, by the rent of grain silos and 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:

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

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:

(7) $$P_{STrt} \sum_i ST_{irt} = wl_{STrt} L_{STrt} + wk_{STrt} K_{STrt}$$

Equation (6) will allow us to determine the unitary storage costs $k_{rt} = P_{STrt}$.

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

The specification of this storage service sector differentiates our work from that of HERTEL et al. (2005) who also incorporate stockholdings in a CGE model but consider that storage is at no cost and fixed and an exogenous limit to the storage capacity.

1.3.3 Equilibrium Conditions

To take stockholding into account in our CGE model, some conditions ensuring market equilibrium have to be modified.

First, the supply and demand of goods for storage modify the equilibrium market prices. So, the market equilibrium conditions determining market prices now include beginning-of-period stocks on the supply side and end-of-period stocks on the demand side.

Then, as in HERTEL et al. (2005), private stockholdings are considered in our model as a form of investment and are thus financed by savings. This modifies the equation ensuring the equality between investments and savings at world level and determining the world interest rate[1].

[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.

1.4 Execution of the Model

Our dynamic model is solved period by period, because agents readjust their decisions in each period, and in two steps for each period. This sequencing of the model resolution deserves some explanation.

As we have already mentioned, consumers and producers base their decisions on expected future market prices. Furthermore, contrary to other agents, farmers do not observe market prices at the time they make their production decisions. To take this specific feature of agricultural sectors into account in our model, we solve it in two steps: first, agricultural production decisions are determined, based on farmers' expectations about market prices, and the prices of factors used for agricultural production are adjusted to ensure equilibrium between farmers' demand and factor owners' supply; the second step puts agricultural quantities produced onto the markets, consumption, savings, investment and stockholdings decisions are taken, and the prices of goods and factors allocated to non-agricultural activities are adjusted so as to ensure market equilibrium. Here our work differs from that of MITRA and BOUSSARD (2008), who are also interested in the effects of stockholdings in the case of imperfect expectations. Indeed, in their work storage is assumed to occur at the time agricultural production decisions are taken and not once harvests are put on the market.

Thus, if a productivity shock occurs in, say, the first period after agricultural producers have decided how much to produce based on their expectations about the future, the effective realized output quantities would not be equal to what farmers had expected. On the other hand, the other economic agents observe market conditions and thus know current market prices at the time they take their decisions. In the first step determining agricultural production decisions, the model is thus solved with a productivity value equal to $E\left[\Phi shock_{ir}\right] = \Phi_{ir}$, and the outcome corresponds to what agricultural producers plan for the future period and therefore it provides the level of production factors they use. In the second step, the model is solved with the shocked productivity, with the levels of agricultural production factors used being set equal to those determined in the first step and consequently they are exogenous. Agricultural supply is determined by the production function, and 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 resulting 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.

2 Simulations and Results

The main purpose of this article is to construct a fully dynamic general equilibrium model with the aim of assessing the effects of stockholding behaviour on the volatility of agricultural prices and able to take account of 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 for illustrative purposes, in order to have initial insight into the impacts of the model specification on the simulated effects of stockholding behaviour on market volatility.

2.1 Definition of Simulations

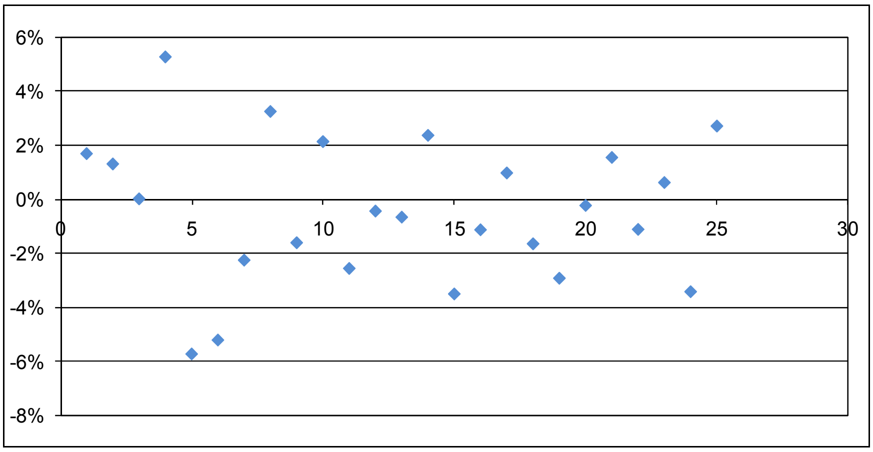
In these simulations we focus on the European wheat sector, which is assumed to be the only sector producing a storable commodity, and study the impacts on this sector of stochastic supply shocks arising in other regions of the world during 25 periods. Assuming that stockholdings only concern one sector and one region in the world is obviously unrealistic, but this assumption is made for better identification of the different simulated effects and thus to make it easier to interpret the results.

2.1.1 Data

To run our simulations, we use the 6th version of the GTAP database calibrated on 2001 economic flows and including tariffs, export subsidies and direct payments for the different regions represented. These data are aggregated to 11 sectors, among which seven are agricultural sectors, and three 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 assumptions to calibrate the data for our dynamic model: we posit that the initial interest rate r, the time preference parameter ρ and the unit capital installation cost φ are all equal to 5%. Furthermore, we reduce by half the supply price elasticities in the agricultural sectors. The supply price elasticities used in the GTAP model are actually rather high, because this model is aimed at simulating the long-term effects of policy reforms. On the other hand, our dynamic framework is intended to simulate short-term effects, and agricultural supply adjusts less easily, notably to price changes, in the short term. The supply price elasticities are reduced by half by reducing the elasticities of substitition between primary factors and between value added and intermediate consumption in the targeted sectors. Then, as in FEMENIA and GOHIN (2009), we assume that the 2001 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 nil. However, the CES form of the production function in the storage service sector does not allow for zero 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 1/5. We conduct some sensitivity analyses for this parameter, the results of which are presented in the last part of this section.

Figure 1. Productivity Shocks



Source: author's calculations

2.1.2 Characteristics of Market 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.

The 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. (2005) to characterize the exogenous production volatility in their model, concern the production quantities or yield, but these data result in fact from producers' decisions, for example, 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% and then conduct some sensitivity analyses 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 in figure 1 and table 1 presents their main distribution characteristics.

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

2.1.3 Benchmark Results

Before focusing on the impacts of stockholding behaviour, 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.

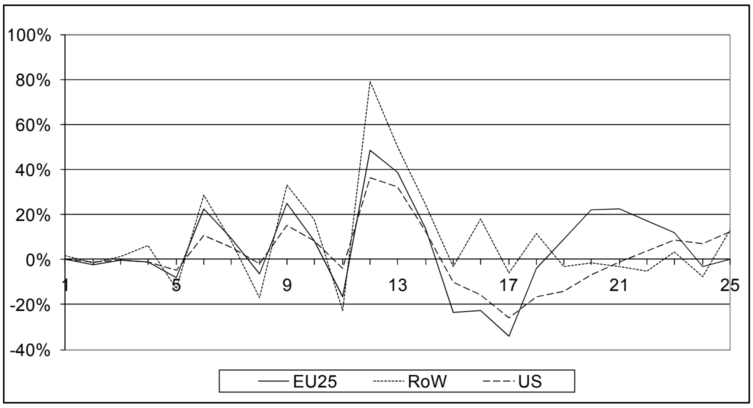
The evolution of wheat output in the three regions of the world is represented in figure 2 and the development of the wheat price is illustrated in figure 3.

Table 1. Distribution Characteristics of Productivity Shocks

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

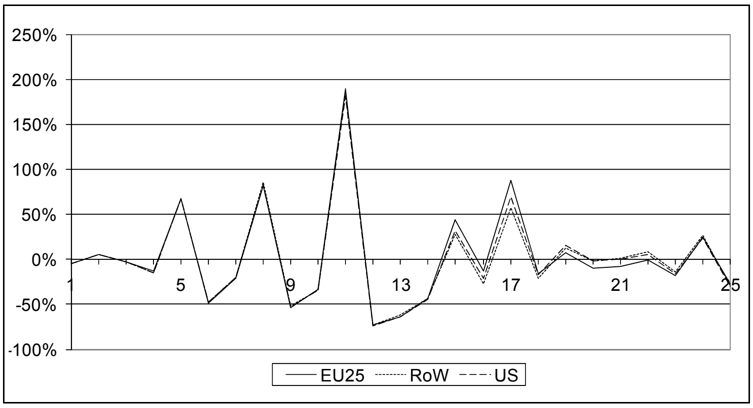
[a] Standard Deviation, [b] autocorrelation.
Source: author's calculations

Figure 2. Wheat Output
(% Change compared with the Baseline)



Source: author's calculations

Figure 3. Wheat Price
(% Change compared with the Baseline)



Source: author's calculations

The first thing to note is that, even if exogenous productivity shocks occur in the RoW only, wheat production in the EU and the US also fluctuates. 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 this trade could create a dampening in market fluctuations at world level *via* a risk sharing mechanism if agents were rational, when expectations are imperfect market fluctuations synchronise and are amplified at the world level. This illustrates one important criticism of the liberalisation of agricultural trade (BOUSSARD et al., 2005).

Table 2. Correlation between Wheat Prices

	EU	RoW	US
EU	1.0	1.0	1.0
RoW	1.0	1.0	1.0
US	1.0	1.0	1.0

Source: author's calculations

Thus productivity shocks range from -6% to +6% (see figure 1) but output fluctuations are much more important: a production increase of more than 50% is observed in the RoW in period 12 and a nearly 40% decrease arises in the EU in period 17, as shown in figure 2. The mechanisms explaining these market evolutions are as follows: if in one period a negative productivity shock occurs in the RoW, leading to an increase in the wheat price and the capital income in the wheat sector, in the next period agricultural producers of wheat readjust their price expectation according to the previously observed price increase. They expect a market price higher than the initial price, and so plan to produce more. If positive productivity then occurs, leading to an even larger harvest than producers had expected, the market price of wheat 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 result in producers not decreasing 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, 8, 11, 15 and 17 (see figure 3). Indeed, these periods follow periods where positive shock occurs (see figure 1), so wheat producers expect a market price decrease. This price expectation, combined with the fact that investment in previous periods was low and that their capital stock has just decreased, induces them to plan to produce less than they initially intended. Because of a negative productivity shock, the harvest is actually much lower than expected (see figure 2). As wheat demand is quite price inelastic, this large decrease of production is conducive to a very large price increase. Following these peaks, producers readjust their expectations and market prices return to lower levels for the following periods.

In the EU and the US, the actual output of producers is 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 with exogenous market fluctuations. As table 3 clearly demonstrates, exogenous productivity shocks in the RoW wheat sector, characterized by a 2.7% standard deviation, can generate output fluctuations characterized by a standard deviation almost 10 times higher. This reveals the difficulty in calibrating the distribution of productivity shocks based on production data. The standard deviations of prices around 55% for wheat are in accordance with the fluctuations observed in figure 3.

Table 3 also shows that other sectors related to wheat are affected in all regions as well, since wheat production is at the mean higher than its initial value, and the mean production of oilseeds and other cereal production is lower at the mean, and this leads to some mean price increases. The cattle and beef sectors are also affected by the fluctuations of grain prices: the mean price increases of grains induce a slight mean increase of cattle and beef prices. Although not as high as in the wheat sector, the standard deviations of output and prices in these sectors are not negligible. 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, farm income is also influenced by these shocks, even if they occur in only one region and one sector: the standard deviation of farm income change in the wheat sector is equal to 104% in the EU, 86% in the RoW and 35% in the US, and the standard deviation of farm income changes in the other cereals and oilseeds sectors is in the range from 5% to 13% (see table 6).

Table 3. Distribution Characteristics of Output and Price Changes Compared with the Initial Values

		Output Changes		Price Changes	
		Mean	**S. D.**	**Mean**	**S. D.**
Wheat	EU	5.1%	19.2%	2.2%	56.7%
	RoW	8.4%	22.0%	1.0%	54.5%
	US	1.9%	14.1%	1.5%	54.5%
Oilseeds	EU	0.5%	2.2%	0.8%	9.4%
	RoW	0.2%	2.0%	0.6%	8.9%
	US	0.3%	1.0%	0.4%	9.1%
Other Cereals	EU	0.4%	1.2%	0.8%	4.7%
	RoW	-0.2%	2.5%	0.4%	7.9%
	US	-0.1%	0.7%	0.3%	5.1%
Cattle	EU	-0.1%	0.2%	0.2%	1.1%
	RoW	0.1%	0.9%	0.1%	2.0%
	US	0.0%	0.5%	0.1%	0.9%
Beef	EU	-0.1%	0.1%	0.0%	0.4%
	RoW	-0.1%	0.6%	0.1%	0.8%
	US	0.0%	0.3%	-0.1%	0.4%

Source: author's calculations

2.2 Impacts of Stockholding

Having described the outcome of the model without storage, we now consider the impacts on the results of stockholding behaviour in the European wheat sector.

2.2.1 Standard Case

In what we call our standard case, we set the historical weighting parameter α to $1/5$ 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 stockholding behaviour is introduced into the model.

We can observe from figure 4 that, compared with the case without stocks, output fluctuations in the wheat sector seem to be slightly smoothed for all regions. But the most interesting result appears in figure 5: here the European wheat price is not synchronized with prices in the RoW and the US. This is also reflected in the correlation between prices shown in table 4: whereas wheat prices in the RoW and in the US are still highly correlated, the correlations between the wheat price in the EU and prices in other regions are reduced by about 25%. Stockholding behaviour, which takes place only in the European wheat sector, tends in fact to "disconnect" the European wheat market from world markets.

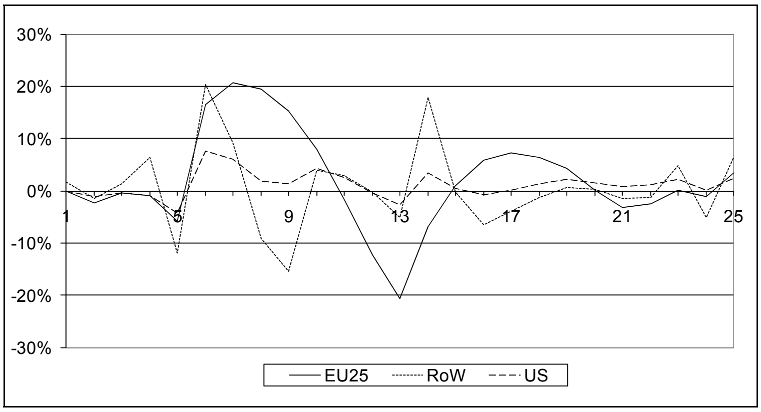
We can also see in figure 5 that price decreases in the European wheat sector are limited but do not totally disappear. They are in fact restrained by the expectations of stockholders concerning the future wheat price and the storage costs. We recall that if stockholders expect a price rise they buy wheat until: $P_{irt} + k_{rt} = \frac{\hat{P}_{irt+1}}{(1+r)}$, which prevents the wheat price

Table 4. Correlation between Wheat Prices

	EU	RoW	US
EU	1.0	0.7	0.8
RoW	0.7	1.0	1.0
US	0.8	1.0	1.0

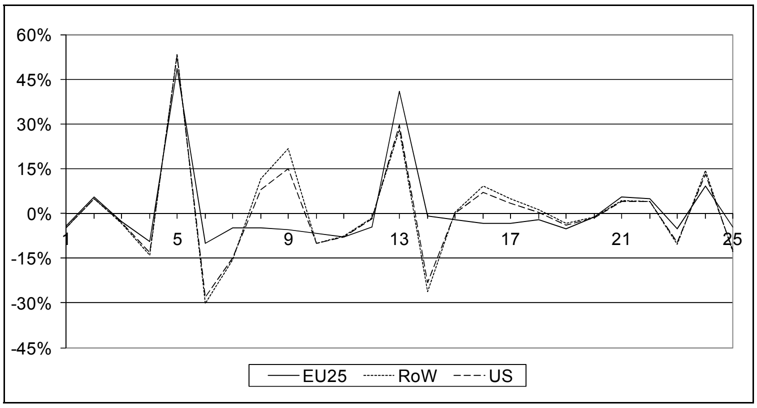
Source: author's calculations

Figure 4. Wheat Output
(% Change compared with the Baseline)



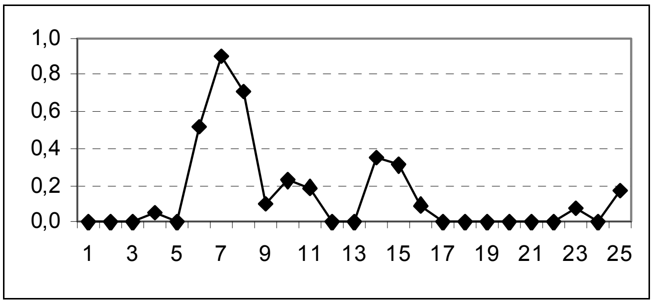
Source: author's calculations

Figure 5. Wheat Price
(% Change compared with the Baseline)



Source: author's calculations

Figure 6. Wheat Stocks in the EU
(in Millions of Tonnes)



Source: author's calculations

from decreasing to less than $\frac{\hat{P}_{irt+1}}{(1+r)} - k_{rt}$. On the other hand, we can still observe some price peaks in the EU, as in other regions. However, these peaks are lower than before the introduction of storage, which can this time be attributed to the liquidation of stocks as illustrated by figure 6.

Due to the effect of big production shocks on the non-rational behaviour of producers, private stockholding behaviour thus seems to limit the occurrence of price peaks while inducing other peaks through stock disposal.

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

WILLIAMS and WRIGHT (1991) point out that, as long as the mean price is endogenous and the responses and feedback of economic agents are taken into account, a stabilization mechanism cannot keep this price unchanged. Our results illustrate their point: compared with the distributions observed prior to the introduction of storage in the model (table 3), mean prices are now lower in all regions and all sectors. In our simulation framework, the mean price decrease is furthermore accentuated by the limitation of the sudden huge price increases attributable to non-rational expectations when storage is not allowed. On the other hand, the effects of stockholding behaviour 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 stockholding behaviour effectively limits price fluctuations, particularly in the European wheat sector, output fluctuations are not systematically increased: apart from a slight increase in the RoW cattle sector, output fluctuations decrease in all regions and all sectors in the table. One explana-

Table 5. Distribution Characteristics of Output and Price Changes (%)

		Output Changes		Price Changes	
		Mean	S. D.	Mean	S. D.
Wheat	EU	2.0	9.4	1.0	14.0
	RoW	0.5	8.0	0.7	17.2
	US	1.1	2.5	0.4	16.3
Oilseeds	EU	-0.3	0.9	0.2	4.0
	RoW	0.0	0.8	0.0	3.8
	US	0.0	0.4	0.0	3.9
Other Cereals	EU	-0.2	0.5	0.2	2.1
	RoW	0.0	1.0	0.0	3.2
	US	0.0	0.3	0.0	2.1
Cattle	EU	-0.1	0.1	0.2	0.4
	RoW	0.0	0.3	0.0	0.7
	US	0.0	0.1	0.0	0.4
Beef	EU	-0.1	0.1	0.1	0.2
	RoW	0.0	0.2	0.0	0.3
	US	0.0	0.1	0.0	0.2

Source: author's calculations

tion for the decrease of output fluctuations is that the stabilization of price also allows producers to stabilize their expectations and in consequence to stabilize their production. So, even if stockholding behaviour can play the destabilizing role stated in the economic literature, it also gives rise to an improvement of other agents' expectations, and the two phenomena 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, as presented in table 6, suggest that the introduction of storage is conducive to stabilization of farmers' incomes in all cases, even when their production is destabilized.

The last point that differs in our results from what is found in the economic literature is that a decrease of price volatility caused by stockholding behaviour is shared by all regions, even though it is more important in the EU. This differs from the view expressed by TYERS and ANDERSON (1992), who stress a risk sharing between regions. Our findings show that stockholders allow all market agents to improve their expectations and in consequence they decrease the endogenous part of price volatility.

2.2.2 Sensitivity Analysis

The simulations presented above suggest that modelling the effect of stockholding behaviour in a dynamic intertemporal CGE framework that assumes non-rational expectations can lead to results on market risks quite different from those commonly found in the economic literature. Indeed, our results suggest that storage actually induces a stabilization of agricultural prices (and incomes), but does not necessarily destabilize output. Furthermore, we find no evidence of a transmission of price volatility from the sector concerned with stockholding to other sectors or regions. However, in order 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%, and 4%.

We demonstrate in table 7 below the changes in standard deviation of outputs, prices and income induced by the introduction of storage for the different volatilities of exogenous shocks.

Table 7. Changes in Standard Deviations Induced by the Introduction of Storage in the Model (%)

			$\sigma_\varepsilon = 1$	$\sigma_\varepsilon = 3$	$\sigma_\varepsilon = 4$
Prices S.D.	Wheat	EU	-37.5	-75.4	-82.6
		RoW	-25.0	-68.3	-71.5
		US	-27.1	-70.0	-73.4
	Oilseeds	EU	-15.8	-57.2	-53.1
		RoW	-17.3	-57.3	-53.2
		US	-17.4	-57.0	-52.9
	Other Cereals	EU	-20.3	-55.3	-50.0
		RoW	-19.3	-59.9	-56.7
		US	-22.2	-59.6	-57.4
Output S.D.	Wheat	EU	-35.1	-51.1	-66.7
		RoW	-10.1	-63.7	-67.1
		US	-21.8	-82.0	-75.0
	Oilseeds	EU	-0.6	-60.8	-62.6
		RoW	-7.7	-60.1	-56.3
		US	-7.5	-60.4	-53.3
	Other Cereals	EU	8.2	-60.7	-63.2
		RoW	-8.7	-60.1	-54.1
		US	-11.0	-57.6	-60.5
Income S.D.	Wheat	EU	-25.0	-23.3	-82.6
		RoW	-29.3	-22.4	-74.8
		US	-24.3	-28.2	-73.2
	Oilseeds	EU	0.0	-33.3	-68.2
		RoW	-17.2	-33.6	-52.7
		US	-19.4	-33.7	-52.9
	Other Cereals	EU	-16.7	-36.0	-77.8
		RoW	-17.2	-34.9	-57.3
		US	-23.8	-38.1	-60.2

Source: author's calculations

Table 6. Standard Deviation of Farm Income Changes (%)

	Without Stockholdings			With Stockholdings		
	Wheat	Oilseeds	Other Cereals	Wheat	Oilseeds	Other Cereals
EU	104.4	11.2	13.4	31.71	4.3	4.9
RoW	85.9	11.1	11.4	24.89	4.8	4.6
US	35.1	13.0	5.4	9.15	5.6	2.2

Source: author's calculations

Regarding these results, it appears that the more volatile the productivity shocks the more the introduction of storage in the model creates stabilization of production, prices and, as a matter of fact, farm income. Actually, this result is not surprising, since moderate productivity shocks, as we have seen, can generate high output and price fluctuations because of the additional volatility arising from the expectation errors of economic agents. In fact, the more volatile productivity shocks are the higher are market fluctuations and the more important are the reductions of expectation errors caused by stockholding behaviour and of fluctuations.

Table 8. Changes in Standard Deviations Induced by the Introduction of Storage in the Model (%)

			$\alpha = 1/3$	$\alpha = 1/4$	$\alpha = 1/5$	$\alpha = 1/10$	$\alpha = 1/50$
Prices S.D.	Wheat	EU	-68.7	-71.1	-75.4	-76.19	-79.28
		RoW	-65.2	-65.0	-68.3	-67.94	-67.37
		US	-66.8	-66.7	-70.0	-69.78	-69.59
	Oilseeds	EU	10.6	-50.9	-57.2	-57.52	-60.10
		RoW	-2.5	-51.3	-57.3	-57.48	-60.29
		US	22.0	-51.0	-57.0	-57.23	-60.07
	Other Cereals	EU	5.2	-49.1	-55.3	-55.43	-55.52
		RoW	-53.6	-55.2	-59.9	-59.63	-59.20
		US	-48.4	-55.1	-59.6	-59.53	-59.86
Output S.D.	Wheat	EU	-13.8	-34.1	-51.1	-57.2	-60.4
		RoW	-58.6	-58.7	-63.7	-63.3	-63.5
		US	-75.7	-80.0	-82.0	-82.2	-81.4
	Oilseeds	EU	223.1	-46.1	-60.8	-63.3	-61.0
		RoW	-41.6	-54.1	-60.1	-60.3	-61.4
		US	63.3	-52.3	-60.4	-60.9	-61.9
	Other Cereals	EU	178.4	-47.6	-60.7	-61.3	-58.4
		RoW	-44.4	-55.2	-60.1	-59.4	-56.8
		US	76.7	-50.1	-57.6	-58.5	-56.9
Income S.D.	Wheat	EU	-53.5	-60.0	-69.6	-74.9	-76.2
		RoW	-67.7	-67.3	-71.0	-70.8	-71.0
		US	-67.7	-71.2	-73.9	-73.8	-73.2
	Oilseeds	EU	45.4	-52.5	-61.8	-64.3	-66.8
		RoW	10.9	-50.8	-56.8	-57.0	-60.0
		US	30.1	-50.8	-56.8	-57.1	-60.0
	Other Cereals	EU	-4.3	-51.9	-63.6	-69.3	-72.0
		RoW	-50.5	-55.3	-59.9	-59.8	-59.7
		US	-32.1	-55.4	-60.2	-60.1	-60.7

Source: author's calculations

Sensitivity to the expectations of stockholders

In our standard case we consider that stockholders form their expectations in the same way as the other agents in the model: the historical weighting parameter α is set to 1/5 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. Thus we run some simulations that consider different values for the historical weighting parameter α, namely 1/3, 1/4, 1/10 and 1/50. The changes in standard deviations of price, output and income induced by stockholding behaviour are presented in table 8.

The first thing to note is that, as for $\alpha = 1/5$, the introduction of storage allows prices to stabilize in all regions, for $\alpha = 1/4$, $\alpha = 1/10$ and $\alpha = 1/50$; and the lower 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 and farm income fluctuations are also dampened when α decreases. In contrast, if stockholders take little account of past information when making their decisions, when $\alpha = 1/3$, their behaviour tends to increase price, output and farm income fluctuations in several sectors and regions.

These results confirm what FEMENIA and GOHIN (2009) pointed out in their paper on the role of expectation schemes, namely that the dynamics of markets are smoothed when agents react slowly to price news.

3 Conclusion

The successive reforms of the CAP raise the question of its price-stabilizing role, and more and more attention is paid to private risk-managing instruments such as storage. The effects of private storage on market volatility have already been widely studied in the economic literature but hardly any of these previous studies takes account of the links between producers', households' and stockholders' decisions in the way that is possible with a CGE model. Furthermore, there is little consideration of the intertemporal decisions of these agents, which is a drawback when studying the effects of an instrument like storage that allows intertemporal arbitrage. Finally, almost all these studies focus on the effect of stockholding on exogenous price volatility and assume rational expectations, which does not allow for the representation of the endogenous part of risk induced by market mechanisms. Speculative stockholders themselves have sometimes been blamed for increasing the volatility on agricultural markets because of their non-rational behaviour.

To address these issues we constructed a dynamic CGE model, taking the intertemporal decisions of economic agents into account, including imperfect expectations and private stockholding behaviour, and then conducted some simulations. These simulations reveal some interesting results which, even if they do not completely contradict the outcome of previous studies, modify some of them.

First, our results illustrate the point made by WILLIAMS and WRIGHT (1991) that a stabilization scheme cannot keep market prices unchanged: indeed, in our framework, the expectation-improving role of stockholding behaviour tends to limit the occurrence and magnitude of sudden price peaks due to an accumulation of expectation errors from other agents. Price peaks still exist under storage but they are mostly due to a liquidation of stocks, and this tends to decrease market prices.

On the other hand, contrary to MITRA and BOUSSARD (2008), we do not find evidence of a systematic destabilizing effect of speculative behaviour on prices. Even if stockholders have imperfect expectations about the future. The only case where this destabilizing effect arises is when speculators take past information less into account than other agents when making their decisions, which seems unrealistic. Moreover, we find that the price-stabilizing effects of stockholding behaviour are all the more important when stockholders take full account of past information to form their expectations. In this case some studies, like WILLIAMS and WRIGHT (1991), argue that if stockholding behaviour stabilizes prices it also destabilizes production. This is not necessarily the case in our framework: when stabilizing prices, stockholding behaviour also stabilizes producers' expectations and production. In the same way, the improvement of expectations allows market prices to stabilize in other sectors than the sector of the storable commodity (wheat in our simulations). Thus, there is no transfer of volatility between regions or between sectors. Furthermore, we find that stockholding behaviour in the EU tends to stabilize income in each region except, once again, if stockholders take less account of past information than other agents to form their expectations.

Furthermore, our results reveal the difficulty in estimating 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 for illustration only: storage applies to the EU wheat sector only and the productivity shocks apply to wheat in the rest of the world. Moreover, we have not taken into account the risk aversion of economic agents that can have an impact on their decisions. Further work should be done to overcome these limitations and to construct a CGE model that studies the effect of a commodity price stabilization program. As pointed out by several authors (NEWBERY and STIGLITZ, 1983; WILLIAMS and WRIGHT, 1991; WEAVER and HELMBERGER, 1977), this analysis of commodity price stabilization should take storage activities into account.

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