Dynamic modelling of agricultural policies: the role of expectation schemes

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Abstract :

The highly disputed effects of agricultural trade liberalisation are mostly simulated with static models. Our main objective in this paper is to evaluate the robustness of the static simulation results to the consistent modelling of dynamic behaviours and to the linked specification of price/return expectations. Focusing on a complete trade liberalisation scenario of arable crop markets by developed countries, we find that available static results are quite robust to dynamic specifications and to most expectation schemes. Endogenous market fluctuations due to expectation errors may appear following trade liberalisation. These fluctuations are nevertheless limited by the many feedback effects revealed by our general equilibrium framework.

Keywords: Agricultural policy, Dynamics, Endogenous fluctuations, Expectation errors

1. Introduction

Agricultural liberalization generally is a major bone of contention in both bilateral and multilateral trade negotiations. Many economic analyses evaluating the impacts of various trade liberalisation scenarios are now available. On the one hand, some studies using complex computable general equilibrium (CGE) models find that the agricultural trade liberalisation will improve the world welfare with benefits shared by most countries (for instance, Anderson et al., 2006 with the Linkage model of the World Bank; OECD 2006 with the Gtapem of the OECD; Hertel and Keeney, 2006 with the Gtap model of the Purdue University, Fontagné et al., 2005 with the Mirage model of the CEPII). On the other hand, others studies question these results and policy recommendations arguing that they rely on implausible modelling assumptions, such as the choice of trade elasticities, the modelling of trade policy instruments or the modelling of labour market imperfections (for instance, Ackerman, 2005; Taylor and von Armin, 2006; Polaski, 2006).

The specification of dynamic economic behaviours in these CGE models is also disputed. In their survey, Piermartini and The (2006) observe that the dynamic CGE models tend to estimate larger gains compared to comparative static models. According to these authors, this comes from the fact that these dynamic models take into account the subsequent increase in the rate of investment and the diffusion of technical change following trade opening. Bouet (2006) argues that this diffusion of technical change, more precisely the relation between total factor productivity and trade openness, is the key factor in the larger effects simulated with dynamic models. Unfortunately the way in which this relation has been introduced in CGE models lacks micro-economic foundations and in fine may artificially increase welfare effects of agricultural trade liberalisation (Bouet, 2006). Moreover the dynamic CGE models used to simulate the effects of agricultural trade liberalisation adopt simple recursive structure: they are built as a succession of static CGE models mainly linked by a jumping variable. Typically the stock of physical capital is updated by the net investment of previous period. The major drawback of these recursive dynamic CGE models is that they do not guarantee time-consistent economic behaviours (Nordas et al., 2006). Typically investments by firms (or savings by households) are specified with ad hoc functions and thus do not derive from well-behaved inter-temporal optimisation programs. In these latter consistent programs, firms decide their investment levels subject to price and factor return expectations. So the investment effect justifying larger dynamic effects also lacks solid macro economic foundations. Finally, these static or dynamic recursive CGE models do not recognize one critical feature of agricultural production, that there is a time lag between production decisions and harvests. This time lag implies that farmers also have to base their production decision on expected rather than on observed market prices.

Our major objective in this paper is to evaluate the robustness of simulation results of agricultural trade liberalisation to the consistent modelling of dynamic behaviours and to the linked specification of price/return expectations.

This joint issue of dynamics and expectations is widely neglected in the large CGE literature simulating the impacts of agricultural policies. The exception is Boussard et al. (2004, 2006). These authors compare an ad hoc dynamic recursive CGE model with one where farmers and investors have naïf price/return expectations. They find that these two versions lead to very different dynamic results and in fine to different policy conclusions. In this paper we extend these works in several directions. First we test different expectation schemes (from naïf to fully rational) and not only the extreme naïf one because econometric analysis on farmers' behaviour generally concludes that farmers have quasi rational price expectations (Chavas, 1999; 2000, Nerlove and Bessler, 2001). Second our benchmark is a static CGE model widely used to assess agricultural trade liberalisation rather than an ad hoc dynamic recursive one. By the way this will allow us clarifying the differences between static and dynamic appraisals of agricultural policy. Third Boussard et al. mostly focus on the nature of farmers' price expectation for next period farm production. In this paper we also pay attention to the issue of the nature of price expectations when agents have to decide saving and investment. A final distinctive feature of our analysis is the specification of land market clearing mechanisms. Due to the lag between production decisions and harvest, farmers engage some inputs (mainly land) in the production process without perfectly knowing their output price. Equally landowners allocate part of their land to farmers without perfect knowledge of the returns provided by alternative land-using activities. Some policy regulations on land uses/returns may provide some frictions on this land market. Accordingly we will test the sensitivity of results to the return expectations by both actors operating on land markets and the eventual existence of land policy regulations.

In this paper we simulate the impacts of a full trade liberalisation of arable crop markets by developed countries, using first standard production, demand and trade elasticities. This radical scenario is often analysed as a benchmark of more realistic scenarios. Our main results are as follows. First the static and rational dynamic models lead to very similar results. Accordingly, dynamic modelling by itself is not sufficient to generate higher or lower gains from agricultural trade liberalisation. Second the specification of price/return expectations in general matters a lot. When the expectations by all economic agents come close to naïve ones, then we obtain a diverging cobweb model with the standard elasticities. On the other hand, with more econometrically founded adaptive price expectations, market results still do not reach limit points but nevertheless stay close to static results. Third the specification of factor return expectations by landowners (when allocating land) or by farmers (when investing in physical capital) also

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matters a lot. In particular, if farmers have different price expectations when deciding production for the next period and investment for all future years, then we again obtain a diverging cobweb model. This outcome also appears when landowners allocate their land on (policy-oriented) imperfect expectations rather on the current return offered by farmers. Accordingly all these results suggest that it is critical to incorporate the different decisions (production, investment, land allocation) and associated expectations of the many actors (farmers, factor owners) operating on farm markets with dynamic models. These multiple dimensions are usually ignored in dynamic partial equilibrium models (for instance, Goeree and Hommes, 2000). This also suggests that some policy interventions (on the land market) may also prevent the interplay of market forces and in fine they may be destabilising. Fourth all these results are obviously dependent on the form of supply and demand functions and on the calibrated price elasticities. Parameters of CGE models are usually calibrated with long-run supply elasticities. As expected, reducing the values of these supply elasticities to reasonable short-run ones reduce the occurrence of diverging cobweb models.

This paper is organised as follows. In the first section, we briefly describe the general structure of current CGE models used to simulate the effects of agricultural policies. We focus the discussion on the specification of dynamic variables (investments, savings). In the second section, we explain the passage from a static CGE model to a dynamic model with rational (or perfect foresight) expectations. In particular we consistently derive production, investment and saving decisions from well behaved inter-temporal optimisation programs. In the third section, we introduce imperfect price and return expectations by the different agents. We detail the closure rules we specify to ensure that all profits are distributed, that product and factor markets clear and that macro-economic identities are satisfied. Section fourth is dedicated to simulation results with the different modelling versions. Finally section five concludes.

2. CGE modelling of agricultural policies: current specifications of dynamic variables

If, by definition, no models can serve for all purposes, it is fair to admit that CGE models are now more and more widely used to assess public policies in general, agricultural policies in particular. The development of richer databases with better representation of agricultural/food sectors and policy instruments certainly contributes to make them more realistic than those used ten years ago. While improved databases supporting these models are always welcome, their technical specifications progressively become the focus of debates. In this section, we first give the main equations structuring current CGE models. Then we discuss how dynamic variables (investment, savings) are specified in both static and recursive dynamic CGE models used to assess agricultural policies.

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2.a. Basic structure

The basic structure underlying current CGE models for agricultural policy assessment can be summarised by the following seventeen equations:

$$L_{ir} = L_{ir}(Y_{ir}, WL_{i,r}, WK_{i,r}, WT_{i,r}) \qquad \perp L_{ir} \tag{S1}$$

$$K_{ir} = K_{ir}(Y_{ir}, WL_{i,r}, WK_{i,r}, WT_{i,r}) \qquad \perp K_{ir} \tag{S2}$$

$$T_{ir} = T_{ir}(Y_{ir}, WL_{i,r}, WK_{i,r}, WT_{i,r}) \qquad \perp T_{ir} \tag{S3}$$

$$P_{ir}Y_{ir} = WL_{i,r}L_{ir} + WK_{i,r}K_{ir} + WT_{i,r}T_{ir} \qquad \perp Y_{ir} \tag{S4}$$

$$L_{ir} = L_{ir}(\overline{L}_r, WL_{i,r}, WL_{j,r}) \qquad \perp WL_{ir} \tag{S5}$$

$$K_{ir} = K_{ir}(\overline{K}_r, WK_{i,r}, WK_{j,r}) \qquad \perp WK_{ir} \tag{S6}$$

$$T_{ir} = T_{ir}(\overline{T}_r, WT_{i,r}, WT_{j,r}) \qquad \perp WT_{ir} \tag{S7}$$

$$Q_{ir} = Q_{ir}(E_r, P_{i,r}, P_{j,r}) \qquad \perp Q_{ir} \tag{S8}$$

$$I_{ir} = I_{ir}(I_r, P_{i,r}, P_{j,r}) \qquad \perp I_{ir} \tag{S9}$$

$$M_{ir} = M_{ir}(PW_{i,r}, PW_{j,r}) \qquad \perp M_{ir} \tag{S10}$$

$$P_{ir} = PW_{i,r}.(1 + tm_{i,r}) \qquad \perp PW_{ir} \tag{S11}$$

$$Q_{ir} + I_{ir} = Y_{ir} + M_{ir} \qquad \perp P_{ir} \tag{S12}$$

$$S_r = S_r(?) \quad \perp S_r \tag{S13}$$

$$I_r = I_r(?) \quad \perp I_r \tag{S14}$$

$$E_r = \sum_i (WL_{i,r}.L_{i,r} + WK_{i,r}.K_{i,r} + WT_{i,r}.T_{i,r} + tm_{i,r}.PWM_{i,r}M_{i,r}) + B_r \quad \perp E_r \tag{S15}$$

$$B_r = \sum_i PWM_{i,r}M_{i,r} \quad \perp B_r \tag{S16}$$

$$I_r = S_r \tag{S17}$$

with the following notations:

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i, j : product

r : region	
Endogenous variables	M_{ir} : net imports
Y_{ir} : production	I_{ir} : investment
L_{ir} : labour	P_{ir} : domestic price
K_{ir} : capital	PW_{ir} : import price
T_{ir} : land	E_r : income
$WL_{i,r}$: labour return	B_r : capital account imbalance
$WK_{i,r}$: capital return	S_r : total savings
$WT_{i,r}$: capital return	I_r : total investment
Q_{ir} : consumption	
Exogenous variables	
$\overline{L}_r$: labour stock	
$\overline{K}_r$: capital stock	
$\overline{T}_r$: land stock	
$tm_{i,r}$: tariffs	

The first fourth equations determine the supply side of the economy. Labour (eq S1), capital (eq S2) and land (eq S3) demands are derived from static cost minimisation programs by firms:

$$\min Cost_{ir} = WL_{i,r}.L_{i,r} + WK_{i,r}K_{ir} + WT_{i,r}T_{ir}$$
$$s.t. \quad Y_{i,r} = Y_{i,r}\left(L_{i,r}, K_{ir}, T_{ir}\right)$$

The CES (Constant Elasticity of Substitution) functional form is usually used to specify the production or dual cost functions. Implicit in this specification is that the capital is, at least, partly mobile between sectors. Output levels are determined by the zero profit condition (eq S4).

The next three equations (eq S5 to eq S7) determine the supply of factors to activities as a function of total factor availability and return by activities. The CET (Constant Elasticity of Transformation) functional form is usually used to implement these equations (with the limited case of perfect mobility). Following equations specify final demand by household (eq S8), investment demand per commodity as a function of total investment (eq S9), foreign supply of products in a reduced form to simplify the presentation (eq S10), the relation between domestic and foreign prices (eq S11), equilibrium on product markets (eq S12).

Domestic saving and investment are for the moment specified in general ways and will be discussed below (eq S13 and S14). Finally the last three equations are macro-economic conditions defining the national income (eq S15), ensuring the balance of payments (eq S16), and the balance between savings and investment (eq S17).

In this stylised static CGE model, agricultural policies are captured by the tariffs imposed on imports. Kilkenny and Robinson (1990) show that the specification of saving and investment variables, more generally the closure rules of macro-economic identities, has no major consequences when assessing the market effects of agricultural policies. Their application concerns the U.S. economy where the agricultural sector plays a limited role. On the other hand, these closure rules may have crucial impacts on welfare effects, even in developed countries (for instance, Gohin and Moschini, 2006).

2.b. Specification of investment and saving dynamic decisions

The choice of a closure rule which ensures that saving equals investment has long been an important issue in static CGE models. As Dewatripont and Michel (1987) note, this closure problem arises because of the dynamic nature of the economy, reflected in the possibility for economic agents to invest or save. Different solutions reflecting modeller's view have been implemented. We discuss the solutions adopted in the four prominent CGE models mentioned in the introduction.

In the static version of the Gtap model and the Gtapem model, saving is a fixed proportion of domestic income. This specification is motivated by the work of Lluch (1973) and Howe (1975) showing that, under the assumptions of static price (and inflation) expectations and a Stone Geary instantaneous utility function, saving is a fixed proportion of the supernumerary income. Then a world bank collects savings from all countries and allocates world saving to regional investments according to expected regional capital returns. These expected capital returns decline with investments according to an ad hoc log-log specification and do not depend on expected good prices. This is equivalent to assume static output price expectations in investment decisions.

In the recursive dynamic CGE models, saving and investment specifications are hardly more complex. In fact most of the dynamics occurs outside of the model proper, i.e. in between solutions. The main exception is the capital accumulation function. In the Mirage CGE model, regional savings are also assumed fixed proportions of regional incomes for each simulated year. These savings are yearly allocated to investments in different sectors and different regions according to present capital returns. This is thus slightly different from previous specifications. The Mirage one assumes that end-of-the-year simulated capital returns will prevail in the next period (so a naïf expectation). In the previous CGE models,

observed capital returns at the beginning of the year (before the implementation of the policy shock) are used as capital return expectations for the next period (so a myopic expectation).

Finally, in the Linkage CGE model, agents are assumed to be myopic and to base their decisions on static expectations about prices. More precisely regional savings represent fixed shares of regional incomes. Regional investment is set residually to balance with domestic and foreign savings, the latter being determined from an exogenous current account surplus or deficit.

To sum up, both static and dynamic recursive CGE models used to assess agricultural policies implicitly specify potentially restrictive expectations scheme for investment and saving decisions. They mostly assume static (myopic) price/return expectations and thus do not recognize the effects of policy shocks on these dynamic decisions. Moreover they do not recognize the lag between (planting) production decisions and (harvesting) output marketing and thus also neglect the expectations associated with this dynamic as well.

3. Dynamic CGE modelling of agricultural policies with rational expectations

Many researches have already analysed the joint impacts of dynamics and price expectations on CGE results. For instance, Rutherford and Tarr (2003) show with a CGE model applied to a small open economy that the static and dynamic rational expectation versions lead to the same results. Bye (2000) also finds similar results from the rational expectation version and the imperfect price expectation version of his dynamic CGE model (investors only have imperfect expectations). By contrast, Thissen and Lensink (2000) or Ballard (1987) find that their results differ considerably between the rational expectation version and the adaptive expectation version of their respective dynamic CGE models. These results suggest that the issue of dynamics and expectations is case specific, depends on the nature of contemplated scenarios and how imperfect are adaptive price expectations.

In this section we explain how we build a dynamic rational CGE model from the previous static CGE model. We first describe the dynamic behaviour of producers, then the dynamic behaviour of consumers and finally define the macro-economic closure rules and steady state conditions. We basically keep the same notations and add the time index t.

3.a. Dynamic modelling of producer behaviour with rational expectations

As usual we assume that firms choose, at each time period, the optimal levels of labour and land and make investment decisions to maximise the value of the firm. We furthermore assume that firms, more generally all agents, face the same certain world interest rate. This is equivalent to assume an efficient world financial capital market. Such an assumption makes sense in the perfect foresight setting of this section.

This implies in particular that the financial structure of firms does not matter. However, to facilitate the comparison with the imperfect expectation case, we assume that firms finance all investment outlays by retaining profits so that the number of equities issued by the private sector remains unchanged. It should be added that this assumption fits well with the structure of farm capital mostly owned by farmers (Barry and Robinson, 2002).

On the other hand, we assume that investment is subject to rising marginal costs of installation and that physical capital, once installed, is fixed (Chavas, 1994; McKibbin and Wilcoxen, 1999). Accordingly the equation determining the mobility of capital is dropped (eq S6). The optimisation program of firms then becomes:

$$\max \pi_{ir} = \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t \left(\hat{P}_{irt}.Y_{irt} - \hat{W}L_{irt}.L_{irt} - \hat{W}T_{irt}T_{irt} - \hat{P}I_{irt}(1+\aleph_{irt}).I_{irt}\right)$$

$$s.t. \quad Y_{irt} = Y_{irt}(L_{irt}, K_{irt}, T_{irt})$$

$$s.t. \quad K_{irt+1} = K_{irt}.(1-\delta_{irt}) + I_{irt} \quad ; \quad K_{ir0} = \overline{K}_{ir0}$$

Expected output prices and factor returns (with a hat) are now specified in the program, δ_{irt} is the depreciation rate of capital and $\aleph_{irt}$ the unit cost of capital installation. We adopt the Uzawa's specification:

$$\aleph_{irt} = \frac{\phi_{ir}}{2}\frac{I_{irt}}{K_{irt}}$$

This producer's program can be solved in two steps. In the first step, we can solve the optimal production, land and labour decisions given expected output prices, expected factor returns and installed capital:

$$\max \hat{W}K_{irt}.K_{irt} = \hat{P}_{irt}.Y_{irt} - \hat{W}L_{irt}.L_{irt} - \hat{W}T_{irt}T_{irt}$$

$$s.t. \quad Y_{irt} = Y_{irt}(L_{irt}, K_{irt}, T_{irt})$$

$$s.t. \quad K_{irt} = \overline{K}_{irt}$$

This leads to equations very similar to eq S1 to S4, the exception being that the capital derived demand equation (eq S2) implicitly determines the residual expected capital return. In the second step, we determine the optimal investment and capital formation per period:

$$\max \pi_{ir} = \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t \left(\hat{W}K_{irt}.K_{irt} - \hat{P}I_{irt}(1+\aleph_{irt}).I_{irt}\right)$$

$$s.t. \quad K_{irt+1} = K_{irt}.(1-\delta_{irt}) + I_{irt} \quad ; \quad K_{ir0} = \overline{K}_{ir0}$$

Equations S6 and S9 are then replaced by the first order conditions of this second step:

$$K_{irt+1} = K_{irt}.(1-\delta_{irt}) + I_{irt} \quad ; \quad K_{ir0} = \overline{K}_{ir0} \qquad \perp \quad K_{irt} \qquad\qquad (R6)$$

$$\hat{W}K_{irt+1} + (1 - \delta_{irt})\hat{P}I_{irt+1}\left(\phi_{ir}\frac{I_{irt+1}}{K_{irt+1}} + 1\right) \qquad\qquad \perp \quad I_{irt}$$

$$= (1 + r)\hat{P}I_{irt}\left(\phi_{ir}\frac{I_{irt}}{K_{irt}} + 1\right) - \frac{\phi_{ir}}{2}\hat{P}I_{irt+1}\left(\frac{I_{irt+1}}{K_{irt+1}}\right)^2 \qquad\qquad \text{(R9)}$$

$$I_{rt} = \sum_i \hat{P}I_{irt}I_{irt} \qquad \perp \quad I_{rt} \qquad\qquad\qquad\qquad \text{(R14)}$$

Equation R6 simply reproduces the dynamic of capital accumulation. Equation R9 implicitly determines the optimal investment by firms and R14 simply aggregates investment at the regional level. To facilitate the interpretation of R9, let's first assume that installation costs are null ($\phi_{ir} = 0$). The right hand side is then the marginal cost of investment in period t evaluated in period t+1. The left hand side is the marginal revenue of this investment: it equals the next period expected capital returns and the next period expected price of (the depreciated) investment good. When installation costs are positive, then the marginal cost and revenue of present investment are augmented by these costs. The last term of this equation takes into account that this installation cost decreases with the capital stock, hence by investing today, this will decrease the installation cost of next-period investment.

The crucial point here is that these optimal investment decisions depend on the expected prices of the investment good and the expected capital returns. The latter depend on the expected prices of outputs and the expected returns to other production factors. Accordingly if an agricultural policy scenario leads to some expected changes in output prices and capital returns, then farmers will react by modifying their investment decisions (and periodic production and input decisions as well). This will have subsequent impacts on future production and markets. Their expectations thus may have dramatic real impacts if they are not self-fulfilling. In the rational (or perfect foresight) case, the assumption is that all individuals have all information necessary to compute the future output prices and factor returns. In other words, their expectations are consistent with the model specification. This suggests that expected prices and returns can be simply replaced by simulated values in previous equations. Hence the lag between production decisions and harvest does not matter.

3.b. Dynamic modelling of consumer behaviour with rational expectations

We also adopt the standard assumption that households allocate their income to consumption goods and savings in order to maximise an inter-temporal utility function. As usual we assume that this utility function is additively separable with a preference for present consumption over future consumption. Households face an inter-temporal budget constraint because they have the possibility to save/borrow

without risk at the world interest rate. This budget constraint ensures that the discounted value of future consumptions does not exceed the discounted value of future incomes. Due to the absence of liquidity constraints, this constraint can also be defined as a sequence of recursive equations of motion on wealth (Pereira and Shoven, 1988). We adopt this specification as it will ease later the specification of household imperfect expectations.

More formally, the optimisation program of the household is given by:

$$\max \quad U_r = \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t U_r(Q_{irt}) = \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho} \right)^t \log(Q_{rt}(Q_{irt}))$$

$$s.t. \quad \hat{W}_{rt+1} - \hat{W}_{rt} = r\hat{D}_{rt} + \sum_i \hat{W}L_{irt}\hat{L}_{irt} + \hat{W}T_{irt}\hat{T}_{irt} + \hat{\pi}_{irt} + \hat{t}m_{irt}\hat{P}WM_{irt}\hat{M}_{irt} - \hat{P}_{irt}.Q_{irt}$$

$$= r\hat{W}_{rt} + \sum_i \hat{W}L_{irt}\hat{L}_{irt} + \hat{W}T_{irt}\hat{T}_{irt} + \hat{t}m_{irt}\hat{P}WM_{irt}\hat{M}_{irt} - \hat{P}_{irt}.Q_{irt}$$

$$= \hat{D}Y_{rt} - \sum_i \hat{P}_{irt}.Q_{irt}$$

$$W_{r0} = \overline{W}_{r0}$$

ρ is the rate of time preference, D the net foreign assets held by the domestic household (positive or negative), W the domestic household wealth which is the sum of domestic assets and net foreign assets, DY the distributed income. This dynamic program is much more complex that the former dynamic producer program because the household must anticipate much more variables (mostly determining future income). The definition of the wealth accumulation equation deserves some explanation. The first terms of the right hand side represent the current income to domestic household: it equals the interest earning of foreign assets, the current labour and land returns, the profits distributed by firms and the tariff receipts. This definition of current income is different from the static one where we introduce the gross capital returns in place of profits (see eq 13). If we add the total investment outlays by firms on the right hand side, then we can get total regional saving:

$$S_{rt} = r\hat{D}_{rt} + \sum_i \hat{W}L_{irt}\hat{L}_{irt} + \hat{W}T_{irt}\hat{T}_{irt} + \hat{\pi}_{irt} + \hat{P}I_{irt}\left(1 + \hat{\mathbf{x}}_{irt}\right)\hat{I}_{irt} + \hat{t}m_{irt}\hat{P}WM_{irt}\hat{M}_{irt} - \hat{P}_{irt}.Q_{irt}$$

$$= r\hat{D}_{rt} + \sum_i \hat{W}L_{irt}\hat{L}_{irt} + \hat{W}K_{irt}\hat{K}_{irt} + \hat{W}T_{irt}\hat{T}_{irt} + \hat{t}m_{irt}\hat{P}WM_{irt}\hat{M}_{irt} - \hat{P}_{irt}.Q_{irt}$$

$$= \hat{E}_{rt} - \sum_i \hat{P}_{irt}.Q_{irt}$$

Accordingly, if we are able to determine the consumption expenditure from the household optimisation program, then national saving is determined by this last equation. We can solve this household inter-temporal program in two steps thanks to the time separability assumption. In the first step, we can determine the periodic optimal good consumption given expected consumer prices and optimal consumption expenditure. This leads to an equation very similar to eq S8 with the income variable

substituted by the optimal consumption expenditure. In the second step, we determine the optimal saving and consumption expenditure. Equation S13 is replaced by the following first order condition:

$$\hat{E}_{rt+1} - S_{rt+1} = \hat{P}C_{rt+1}.Q_{rt+1} = \left(\frac{1+r}{1+\rho}\right)\hat{P}C_{rt}Q_{rt} = \left(\frac{1+r}{1+\rho}\right)\left(\hat{E}_{rt} - S_{rt}\right) \quad \perp \quad S_{rt} \tag{R13}$$

$\hat{P}C_{rt}$ is the expected composite consumer price. Again we only get an implicit equation determining the optimal evolution of consumption expenditure and saving in function of expected consumer prices and expected incomes. For instance, if the household expects a change in the composite consumer price, then he will modify his saving and consumption decisions. This will in turn alter market equilibriums, prices and future household decisions.

If the policy shock affects a small sector like the farm sector in developed countries, then we do not expect a priori that the issue of price and return expectations will significantly influence these macro-economic saving/consumption expenditure levels. This issue may be more severe for economy more dependent on their farm sector.

3.c. Macro-economic closures and steady state solutions

From the initial static CGE model, so far we mainly modify the equations determining capital supply (eq S6 to R6), the investment by firms (eq S9 to R9), regional investment (eq S14 to R14) and regional saving (eq S13 to R13). In passing we also slightly redefine the current income by replacing the capital account imbalance (equal to the opposite of the current account imbalance) by the earning of foreign assets (first term of R15) so that the dynamics of foreign assets accumulation is taken into account:

$$\hat{E}_{rt} = r\hat{D}_{rt} + \sum_i \hat{W}L_{irt}\hat{L}_{irt} + \hat{W}K_{irt}\hat{K}_{irt} + \hat{W}T_{irt}\hat{T}_{irt} + \hat{t}m_{irt}\hat{P}WM_{irt}\hat{M}_{irt} \quad \perp \quad \hat{E}_{rt} \tag{R15}$$

To clarify, the two specifications S15 and R15 are equivalent if the interests on foreign assets always equal the current account imbalance. This condition makes sense in the long run, steady state solution because one country can not indefinitely accumulate foreign assets or debts. However the specification R15 allows specifying the dynamic of foreign assets/debts which is given by:

$$D_{rt+1} - D_{rt} = rD_{rt} - B_{rt} \quad ; \quad D_{r0} = \overline{D}_{r0} \quad \perp \quad D_{rt} \tag{R18}$$

This equation is a simple macro-economic identity satisfied at each period. Expectations enter this equation through the capital/trade account imbalance. In static CGE models different rules concerning current/capital account imbalances can be specified reflecting modellers' view. For instance, in the standard static version of the Gtap model, the current account imbalance is endogenous while fixed at the observed initial level in the Linkage model. This obviously implies different effects on the real exchange rate and current income (see equation 15). By extension this also implies different saving decisions and has important implications on farm-dependent economies. But the macro-economic closure of these static CGE models is still ensured due to the fact that investment, either regional or world, is driven by saving.

In dynamic CGE models, different "trade" rules consistent with the assumption on the financial capital markets are possible as well. The rules will also have some real impacts. On the other hand, if expectations by all economic agents are fully rational, then we can show that global savings equal global investment (see Appendix A). This is indeed intuitive: since economic agents have full rationality, households necessarily know investment levels by firms and thus adjust their consumption and saving decisions so as to finance these investments.

Solving an infinite horizon dynamic CGE model imposes the modeller to define steady state conditions at some future terminal period. The equations determining investment (equations R6 and R9) and saving (equation R13) relates current decision to next period decision given expected prices and returns. As usual, we assume that in a steady state investment equals capital depreciation, the household wealth does not grow and foreign debts/assets are stable as well. All these relations are consistent with the macro-economic identities. In fact this also implies that regional saving equals regional investment.

4. Dynamic CGE modelling of agricultural policies with imperfect expectations

The previous section makes clear that different price and factor returns expectations are formulated by all economic agents. In the rational expectation case, the assumption is that all economic agents are fully rational. In this section we consider the other polar case where no economic agents have full information on the evolution of the global economy and thus have imperfect expectations on prices, factor returns and future interest rates as well. This bounded rationality of economic agents is justified by the positive and significant cost of obtaining and processing market information (for instance, Brock and Hommes, 1997).

Before detailing agents' behaviour and macro-economic closures with imperfect expectations, it is worth stressing that, by definition, expected values are equal to the "true" future values in the fully rational dynamic CGE model. This implies that at the first period consumers and producers base their decisions on the "true" future market prices. Decisions taken during the second period rely on the same future market prices. Thereby there is no need to re-evaluate the model for each period: the solution computed in the

first period corresponds to the optimal choice for the following periods (Ginsburgh and Keyzer, 1997). This need to solve the model for all periods simultaneously can lead to some computational issues (Dixon et al., 2005). On the other hand, in the imperfect expectation case, producers and consumers base their decision on expected prices which are not necessarily the true future market prices. Thus if during the second period they realize that their first period expectations were wrong, they will modify their expectations concerning the future periods and revise their production /investment / saving plans. Thereby the model has to be evaluated at each period and only the results for the on going period matter because they will be used to form the next period expectations and to give new starting conditions for the following period (new stock of capital, household wealth and country net debt). The model is thus iteratively solved, period by period, even if at each period agents define plans for many years.

4.a. Dynamic modelling of producer behaviour under imperfect expectation

In addition to the formulation of expectation schemes on prices, factor returns and interest rate, two main changes are introduced in the inter-temporal program of the producer. First we consider that firms optimize their investment over a finite horizon rather than indefinitely because they have limited knowledge about output price, capital returns and interest rate in the far future. In other words, we assume that firms consider that, at some date, their investments will equal their capital depreciation. Indeed this firm steady state condition may never appear because firms periodically revise their plans but this formulation defines the current optimal investment plan for firms, including the current investment. We also assume that firms perfectly know the current price of the investment good when they invest, i.e. when they buy it. To be complete, this corresponds to the following program:

$$\max \pi_{ir0} = \sum_{t=0}^{T} \left(\frac{1}{1+\hat{r}} \right)^t \left(\hat{W}K_{irt}.K_{irt} - \hat{P}I_{irt}(1 + \aleph_{irt}).I_{irt} \right)$$

$$s.t. \quad K_{irt+1} = K_{irt}.(1 - \delta_{irt}) + I_{irt} \quad ; \quad K_{ir0} = \overline{K}_{ir0}$$

$$s.t. \quad I_{irT} = \delta_{irT}K_{irT}$$

$$s.t. \quad \hat{P}I_{ir0} = PI_{ir0}$$

First order conditions of this program are exactly given by equations R6 and R9. The only difference (except the formulation of expectation) is the introduction of a terminal/ steady state condition stating that firms do not expect to indefinitely grow or contract. The solution of this program is a firm investment plan which depends on the expected capital returns and expected price of investment goods. It mainly gives the current investment which will affect current market equilibrium. The investment levels planned for future periods may indeed be revised in the next period if the firm expectations do not materialize. Finally we

note that firms need to anticipate over T periods the price of investment goods, their capital returns and interest rate. Only the current price of the investment good is perfectly known when firms purchase it.

The second modification concerns the intra-temporal production and input decisions and intends to capture the time lag between production decisions and harvests. This modification applies to some activities only and this does matter with imperfect expectations. All the "cobweb" literature focuses on the production decision of firms but, to our knowledge, pays little attention to the input decisions. In our CGE setting both decisions are modelled, forcing us to classify inputs according to their introduction in the production process. In this article we focus on the arable crop markets where the one-year decision fits well with the annual periodicity of CGE models.

We assume that arable crop farmers decide their acreage choice given expected output prices and expected input prices (in this theoretical section, only labour; in the empirical section, we also include fertilizers, pesticides, etc.). On the other hand, we assume that they can observe the current price of the land they decide to use. In other words, farmers pay their land input to landowners once they use it. Their intra-temporal program is thus:

$$\max \hat{W}K_{irt}.K_{irt} = \hat{P}_{irt}.Y_{irt} - \hat{W}L_{irt}.L_{irt} - WT_{irt}T_{irt}$$
$$s.t. \quad Y_{irt} = Y_{irt}\left(L_{irt}, K_{irt}, T_{irt}\right)$$
$$s.t. \quad K_{irt} = \overline{K}_{irt}$$

From this program, we derive the optimal production, labour and land derived demands:

$$L_{irt} = L_{irt}\left(\hat{P}_{irt}, \hat{W}L_{irt}, K_{irt}, WT_{i,r}\right) \qquad \perp L_{ir} \tag{I1}$$

$$T_{irt} = T_{irt}\left(\hat{P}_{irt}, \hat{W}L_{irt}, K_{irt}, WT_{i,r}\right) \qquad \perp T_{ir} \tag{I2}$$

$$Y_{irt} = Y_{irt}\left(L_{irt}, K_{irt}, T_{irt}\right) \quad \perp \quad Y_{irt} \tag{I3}$$

Because some activities are asking some land before other activities, landowners must decide to offer land to activities before knowing the land returns that other activities may offer. Accordingly landowners must allocate part of their land with imperfect information. Indeed the landowner has two decision periods: one at the "beginning" of the year where some lands are allocated to arable crop activities given expected land returns by other activities; one at the "end" of the year to allocate remaining lands given observed land returns offered by other activities. Again this issue does not appear with the full rational case. The program of the landowner at the beginning of the period is given by:

$$\max \sum_{j} \hat{W}T_{jrt}T_{jrt}$$

$$s.t. \quad \overline{T}_{rt} = T_{rt}\left(T_{jrt}\right)$$

$$s.t. \quad \hat{W}T_{irt} = WT_{irt} \quad i \in ac$$

The program at the end of the period is:

$$\max \sum_{j \notin ac} WT_{jrt}T_{jrt}$$

$$s.t. \quad \overline{T}_{rt} = T_{rt}\left(T_{jrt}\right)$$

$$s.t. \quad T_{irt} = T_{irt}^{*} \quad i \in ac$$

ac stands for the arable crop activities and T_{irt}^{*} the allocation of land to arable crop activities in the beginning of the year. These two programs give new land supply functions:

$$
\begin{aligned}
T_{irt} &= T_{irt}\left(\overline{T}_{rt}, WT_{irt}, \hat{W}T_{jrt}\right) i \in ac, j \notin ac \\
T_{jrt} &= T_{jrt}\left(\overline{T}_{rt}, T_{irt}, WT_{jrt}\right) i \in ac, j \notin ac \qquad \perp T_{ir}
\end{aligned}
\tag{I7}
$$

Anticipating the simulation results, some may object at this point that the land markets are heavily regulated in some developed countries with some price and/or quantity restrictions. Indeed price regulations provide information to both landowners and farmers and thus they have better information on land returns, if not the true one as modelled here. However this price regulation may prevent some cost adjustment by farmers and hence leads to subsequent large production effects. In the simulation section, we will explore if one stylised land price regulation is stabilising or destabilising. If quantity regulations on land uses exist, they reduce the price elasticity of farm production, hence the potential importance of price expectation scheme and the occurrence of diverging cobweb model.

Implementing these new equations describing the behaviour of arable crop farmers and landowners modify the resolution of the model. In fact we first solve these equations to determine optimal production, land use and variable input uses by farmers given expected prices/returns and installed capital. In this first step we also determine land returns paid by the arable crop activities. Then in a second step we plug these results in the full CGE model (and remove the corresponding equations). The full CGE model will determine the current prices of arable crop products and the observed capital return will be determined residually. This full CGE model also determines the optimal investment plans by all agents and hence the availability of capital stock for next period.

4.b. Dynamic modelling of consumer behaviour under imperfect expectation

In a similar way we consider that the household optimizes his consumption and saving plans over a finite horizon rather than indefinitely because he has limited knowledge about the evolution of distributed income, consumer prices and interest rates. We consider that, after some dates, the household anticipates that the consumption expenditure equals the annual distributed income (Devarajan and Go, 2000). Focusing on the "upper-stage" consumption/saving decisions, this program is defined by:

$$\max \quad U_r = \sum_{t=0}^{T} \left(\frac{1}{1+\rho} \right)^t \log(Q_{rt})$$

$$s.t. \quad \hat{W}_{rt+1} - \hat{W}_{rt} = \hat{D}Y_{rt} - \hat{P}C_{rt}.Q_{rt}$$

$$\hat{D}Y_{rT} = \hat{P}C_{rT}.Q_{rT}$$

$$W_{r0} = \overline{W}_{r0}$$

Solving this program leads to the necessary first order conditions R13 and the additional terminal condition stating that the consumption expenditure equals the distributed income in the long run. Combining these two sets of conditions leads to:

$$PC_{r0}Q_{r0} = \hat{P}C_{rT.}Q_{rT} \left(\frac{1+\rho}{1+\hat{r}} \right)^T = \hat{D}Y_{rT} \left(\frac{1+\rho}{1+\hat{r}} \right)^T$$

The current consumption expenditure thus depends on the expected distributed income in the long run and on the expected interest rate (to simplify notations, we assume here a constant expected interest rate over the projection period like the time preference parameter). The current total regional saving is then given by:

$$S_{r0} = E_{r0} - P_{r0}.Q_{r0} = E_{r0} - \hat{D}Y_{rT} \left(\frac{1+\rho}{1+\hat{r}} \right)^T = E_{r0} - \left(\hat{E}_{rT} - \hat{P}I_{rT} \left(1 + \hat{\aleph}_{rT} \right) \hat{I}_{rT} \right) \left(\frac{1+\rho}{1+\hat{r}} \right)^T \qquad \text{(I13)}$$

In other words, the current total regional saving depends on the current total income, the expected level of distributed income in the long run and the expected evolution of the interest rate. In many static or dynamic recursive CGE model, saving is a fixed proportion of total income. We see from this equation I13 that this implies particular price and income expectations from households.

4.c. Macro economic closures under imperfect expectation

Household saving and firm investment decisions are made completely apart in the imperfect expectation setting. Whatever these specifications of these expectation schemes are, there is a chance that a country net foreign debt accumulates over the years, possibly leading to some correcting macro-economic policy

(for instance, fiscal policy, see Devarajan and Go, 1998). There is also a great chance that they do not de facto ensure that investment equals saving at the world level. We thus need a new equilibrium mechanism ensuring this equality between investment and saving. We adopt a classical closure assuming that the current world interest rate is endogenous and that asset markets are perfectly integrated across regions. This endogenous interest rate at least appears in the current investment, whatever the expectation schemes. For instance, if total savings are lower than total investments, then the current interest rate increases such as to reduce investment and restore the equilibrium at the world level.

5. Simulations

Having detailed the main differences between static and consistent dynamic CGE models with different expectations schemes, we are now in a good position to assess the robustness of simulation results on agricultural policies to the joint issue of dynamics and expectations. We implement these different versions using the inescapable GTAP database (we use the version six calibrated on the 2001 economic flows) and the different elasticities (substitution elasticities between inputs at the production side, factor mobility elasticities, "Armington" trade elasticities and price/income demand elasticity) usually used in agricultural policy assessments (Keeney and Hertel, 2005). As usual we reduce the dimensions of the model by aggregating some regions and products. We retain 26 commodities keeping all farm and food products and only 3 regions (the European Union (EU), the United States (US) and the Rest of the World (RoW)) in order to reduce computation time in the dynamic rational expectation case. All these information are sufficient to calibrate the static CGE model. In order to calibrate the dynamic versions, with rational or imperfect expectations, we need additional information. Basically we follow Devarajan and Go (1998) assuming that the initial point is a steady state and the initial interest rate/ preference parameter/unit capital installation cost all equal 5%.

As usual we consider a rather extreme agricultural policy scenario: we assume that the EU and the US remove all their trade barriers on arable crop products (export subsidies and import tariffs on wheat, coarse grains and oilseeds). On the other hand, we assume that the RoW keeps all farm policy instruments at initial levels. Furthermore we do not change policy instruments on other farm and food products.

5.a. Results from the static model

Impacts on selected commodities from the static CGE model are provided in Table 1. As expected, we find that the EU production of cereals declines, by 6 per cent for wheat, by 6.9 per cent for coarse grains. Basically removing trade barriers puts downward pressure on the EU domestic prices. We find limited price decreases, by 0.9 per cent for wheat and one per cent for coarse grains. Ex post supply elasticities are

thus considerable as usual in static CGE models because production factors are quite mobile. In fact we mainly observe a decrease of land returns paid by cereals activities (by 12 per cent) leading to some reallocation to other activities. In particular the EU oilseed production slightly increases (by 0.6 per cent) as this European sector is not initially protected by trade measures. We equally observe a slight increase (by 0.2 per cent) of the European cattle production. In addition to the reallocation of land, this sector benefits from the decrease of cereal prices.

(Insert table 1)

By contrast, the US and RoW productions of cereals expand (by less than one per cent) because these sectors initially receive less protection than the EU sectors.[1] They even experience a slight increase of domestic price (around 0.2 per cent) because they enjoy greater demands for their products. Finally impacts on US and RoW productions of oilseeds and cattle are again of the opposite sign, i.e. these productions decrease because land is attracted in the cereal sectors and the cereals are slightly more expensive.

5.b. Results from the dynamic rational expectation model

In a dynamic model, we inevitably need to first establish a baseline before contemplating the effects of a policy scenario. In order to make results comparable to the previous static ones, we assume in the baseline no exogenous growth, more generally no changes in exogenous variables from the initial period until the steady state solution. So the baseline is simply a replication of the 2001 economic flows over the projection period. Below we report the results for a 15 years time horizon. We perform the same experiment using a 20 year time horizon. Results are qualitatively similar because, as we will see, there is a rapid convergence to the steady state solution.

Before analysing results, we finally mention that in a dynamic model the timing of policy shocks can be specified as well. For example, we can investigate the effects of a rapid versus a slow trade liberalisation. Due to our crude baseline for this paper, we also specify a very crude implementation of the trade liberalisation choc. We assume that it is accomplished in the third year of our projection period (the motivation is provided below).

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[1] More precisely the US protection on arable crops is lower than the EU ones in the initial GTAP database, partly because all U.S. trade measures are not included in this database (like food aid, export credit; more on this point in Gohin and Levert, 2006) while the levels of EU agricultural policy instruments tend to be overestimated (more on this point in Femenia and Gohin, 2009).

We find that in the steady state impacts on previous selected commodities are exactly equal to those obtained with the static CGE model. While the move from a static CGE model to a dynamic rational expectation one is rather complex and that the resolution of the latter is much longer (few seconds for the static CGE model, one hour for the latter using the same computer), this may appear disappointing. In fact this result is not particularly surprising because a consistent dynamic rational expectation CGE model mainly gives micro-economic foundations to the saving and investment decisions. But these macro-economic decisions were not fundamentally modified in our policy experiment because agriculture is a small sector in developed countries. Moreover the sectoral impacts simulated by the static CGE model were also quite limited because land returns, rather capital returns, capture much of the shock. Finally this result has already been obtained by Rutherford and Tarr (2003) who simulate larger trade policy shocks (see also Devarajan, 2002).

Put in another way, this gives confidence on the long run impacts simulated by static CGE models, once one admits the rational expectation hypothesis. With respect to the debate on agricultural policy and the potential benefits of trade liberalisation, we thus find that dynamic modelling with rational expectations is not sufficient to generate larger, positive or negative, effects than the simple static approach (assuming away "ad hoc" productivity effects from trade opening).

Yet this does not mean that dynamic modelling with rational expectations is not worthwhile. For instance this provides the transition path from one to another steady state. Figure 1 below provides the percentage evolution of European production and price of wheat following trade liberalisation. We fully implement the trade liberalisation in the third year ("2003"). It is interesting to note that one year before the trade liberalisation European wheat producers already start decreasing their production (by 0.4 per cent). In fact investment in the wheat European sector decreases in the first two years by nearly 20 per cent, so that the capital stock in this sector adjusts downwards. Consequently the European price temporary increases (by 0.2 per cent). This suggests that the timing of trade liberalisation, more precisely the early announcement, matters in that rational expectation case because producers (more generally economic agents) already adjust to future market conditions. From a policy perspective, this also suggests that, in this rational expectation setting, the impacts of anticipated shocks can already be smoothed by economic agents.

(Insert figure 1)

Nevertheless this figure also shows that the major effect occurs during the year of liberalization. For instance, the European production of wheat already declines by 5 per cent in this first "liberal" period compared to 6 per cent in the steady state. This suggests that, even if the dynamic of capital accumulation takes time, most production adjustments occur with the optimal combination of intra-temporal variable

inputs (fertilizers, pesticides, labour and land). In other words, short run price supply elasticities are still consequent (around 5) and much larger than those usually adopted in partial equilibrium models focused on agriculture (around 0.5). This is so because first substitution elasticities in production technologies are unchanged and second capital returns are a modest production cost in the initial GTAP database. From a modelling perspective, this suggests that fixing the annual capital stock alone is not sufficient to get more econometrically founded short run price elasticities. Either substitution elasticities or the mobility of other factors (such as land or labour) must be reduced in order to get more realistic supply response.

5.c. Results from the dynamic imperfect expectation model

Implementing the dynamic imperfect expectation model also requires to determine the expectations on output prices, input prices, factor returns and the interest formulated by firms, factor owners and households. In this paper, we consider different variants on the arable crop farmer expectations when they decide their next period production levels, on the landowner expectations when they decide their land allocation and on firm expectations when they plan their investment. On the other hand, we maintain the same assumptions regarding household expectations concerning future distributed income and economic agents concerning future interest rate. In practical terms, we adopt the usual specification that current saving is a fixed proportion of current total income. In other words, we assume that consumers expect that their terminal distributed income is proportional to the current total income (see equation I13). As regard to the future interest rate, we simply assume that all agents expect that current interest will prevail in the future (so naïf interest rate expectation).

The exact nature of price expectations formulated by arable crop farmers for next period production is quite disputed in the economic literature. In a nutshell, the rational expectation assumption is made most of the time because it is elegant and consistent with other modelling specifications. This implicitly assumes that the information is costless. On the other hand, some recognize that collecting and processing information is costly: if these costs are high, adaptive and even naïve expectations can in fact be rational and there is an optimal use/search of information (Just and Rausser, 2002). Unfortunately this use of information is difficult to measure. It should be added that the econometric identification of farmers' expectations is made even more complex when there are public interventions on farm markets. To prevent these two issues, Chavas (1999, 2000) performs econometric estimations on the price expectations by non-subsidized U.S. livestock farmers and thus exploit the dynamics of animal production to reveal the use of information. He finds that most farmers exhibit quasi rational expectations. On this ground, we assume that, in a 'liberal' world, arable crop farmers would formulate their price expectations for the next period

using past price information. We slightly simplify the analysis by assuming that the arable crop farmers have Nerlovian (adaptive) price expectation scheme for next period prices:

$$\hat{P}_{irt} = \hat{P}_{irt-1} + \alpha\left(P_{irt-1} - \hat{P}_{irt-1}\right) = \alpha P_{irt-1} + (1-\alpha)\hat{P}_{irt-1} \quad with \quad 0 \le \alpha \le 1$$

The parameter α is the weight given to the previous period market price compared to all the earlier ones. In fact the lowest this parameter is, the greatest quantity of past information is taken into account. At the extreme, if this parameter equals zero, then we end up with static price expectations. At the opposite, when this parameter equals one, we end up with naïve price expectations. We report below the results of our policy experiment using different values for this parameter. In the central case, we assume that this parameter equals 1/3.

In a CGE model we also need to assume the nature of firms' expectations on input prices, factor returns, price of investment goods for their variable input and investment decisions. In the standard case, we also assume adaptive expectations with the same weighting parameter α. We also need to assume the nature of landowners' expectations on land returns in order to allocate part of their lands to some activities (see section 4.a). Again we assume adaptive expectations with the similar weighting parameter in the standard case.

Below we focus the discussion on European impacts as they are the most contrasted. We first discuss results with the assumption of the same weighting parameter in all decisions. Then we analyse the sensitivity of results to the weighting parameter, moving from naïve case to nearly static expectations. Third we present results when we assume different expectation schemes by firms when they invest. Fourth we examine the issue of landowner expectations. Finally we examine the sensitivity to substitution (supply) elasticities.

i/ Standard case

Figure 2 provides the results for the European wheat market from agricultural trade liberalisation under imperfect expectations. We also report the previous results obtained with rational expectations. The first result to note is that the results do not converge to a steady point after 12 years of liberalisation (recall that we implement the trade liberalisation in the third year). We solve the same model over 30 years and the model still does not reach a steady point. On the other hand, we never see a diverging system: the European wheat price changes from the baseline are always comprised between minus 5 per cent and 3 per cent and the European wheat production changes are bounded between minus 8 per cent and 4 per cent. In fact the figure 2 shows that these dynamic imperfect expectation results move around the dynamic rational

expectation results and thus also around the static results. Figure 3 provides the same information on the European coarse grains market. From this figure, we can better observe that every two years, the imperfect expectations results are higher (and then lower) than the corresponding rational ones.

(Insert figure 2 and 3).

In both figures, we observe that the impacts obtained with imperfect expectations are much more severe when the trade policy shock is implemented. In particular the European price of coarse grains decreases by as much as 10 per cent in the third year, compared to 2 per cent in the rational expectation case. This is so because farmers did not anticipate the forthcoming price decrease and thus maintain their production levels during the first three years. By contrast, they already decrease production in the second year (investment in the first year) in the rational expectation case.

From a policy perspective, these results suggest that the agricultural trade liberalisation generate "endogenous" price fluctuations on agricultural markets, i.e. generated because of imperfect expectations by agents. This price fluctuation around the steady state remains however limited, by at most 4 per cent for both cereals.

ii/ Sensitivity to the historical weighting parameter

In both the CGE literature (for instance Ballard, 1987) and the "cobweb" one (for instance, Hommes, 1994), the α historical weighting parameter is shown to have significant impacts on market dynamics. Basically divergence of the system is more likely when this parameter gets close to one (in fact the basic cobweb model with naïf expectation). In this sensitivity analysis we vary this parameter from 0.1 (nearly myopic) to one (completely naïf) for all dynamic decisions (next year production, investment, land allocation).

Figures 4 to 7 give the results of this sensitivity analysis. It appears first that when we assume naïf expectations, the dynamic simulated by the imperfect rational model quickly diverges. In particular we find that the European corn market price decreases by as much as 60 per cent three years after the shock (figure 7). The wheat price also significantly decreases (by 25 per cent, figure 5). We stop the resolution of the model as we then encounter some productions and prices going to zero. So using "standard" (but very high) CGE elasticities and naïve expectations leads to a diverging system and crazy endogenous fluctuations. On the other hand we observe that the dynamic is much more smoothed when agents slowly react to price news. Let's focus on the case when alpha equals one half. We find that the system is not diverging after 15 years. More precisely, the price and quantity fluctuations on the wheat market are growing over time while those on the coarse grains are contracting.

From a modelling perspective, this suggests that it is useful to introduce cross market relationships as they tend to modify supply and demand curves and reduces the occurrence of diverging dynamic system. From a policy perspective, this result suggests that before implementing sectoral policy (in this example on wheat) policy makers should be aware of the feedback effects from other production sectors.

(Insert figures 4 to 7)

iii/ Sensitivity to expectations for investment

In the dynamic modelling with imperfect expectations, firms define each year an investment plan for future years. We need expectations on the future capital returns and future price of investment goods in order to compute this plan. So far we adopt the same expectations as for the next period production. Here we consider another case usually implicitly adopted by the cobweb literature. We assume that the capital is fixed over all projection periods. This is equivalent to assume static expectations for investment purposes. We adopt this assumption for all firms. On the other hand, we maintain standard expectation assumptions on intra-temporal decisions. Results for the European wheat market are reported in figure 8. We observe that the dynamic of the model diverges. More precisely we end up with zero price solution in the year "2015", so the model stops running. We observe that the fluctuations of quantity and price grow over time. By contrast, these fluctuations were bounded in the standard case (see figure 2).

(Insert figure 8).

The mechanism at work is the following. In the first two years following the trade liberalisation ("2003" and "2004"), impacts are similar because the capital used in production has still not changed. In the third year ("2005"), the capital stock decreases in the standard case because producers start reducing their investment in the previous year ("2004"). So the production is going down and price slightly recovers in this third period. For instance, the European wheat production decreases by 6.1 per cent (compared to the baseline) and the price only decreases by 1.7 per cent. They are in fact close to the final steady state solution we get from the dynamic rational expectation model. By contrast, the production decrease in "2005" is lower in the fixed investment setting (by 3.8 per cent), so the wheat price remains low (3.2 per cent). This greater supply level (compared to the steady state solution) we get in the third year following trade liberalisation induces a diverging cobweb.

A graphical analysis may help to clarify this mechanism. In the first graphic, the supply curve is fixed and the demand curve shift inwards following trade liberalisation. In the third year, production increases compared to the initial point, leading to a diverging cobweb. By contrast, the supply curve shifts in the

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second graphic during the third period because producers already reduce their investment. So production in the third year no longer expands (compared to the initial point), leading to a converging cobweb model.

(Insert graphics 1 and 2)

To our knowledge, this feedback mechanism occurring from investment and capital accumulation on the cobweb dynamic is seldom acknowledged, if not simply omitted. This is so because most of this literature relies on partial equilibrium analysis, ignoring firm production costs and the different possibility firms have to respond to price shocks. From a modelling point of view, the CGE setting used in this paper thus reveals new feedback mechanisms preventing diverging dynamics. From a policy perspective this again suggests that some (input) market forces prevent large endogenous market fluctuations.

iv/ Sensitivity to landowner expectations

The lag between production decisions and harvest is often advanced as an agricultural specificity. While true, this lag also exists in other sectors. In this section, we focus on landowner expectations and the interference of land price regulations. Because landowners allocate part of their land to some activities before knowing returns provided by alternative activities, they have to formulate expectation scheme as well. Up to now we assume that the land returns paid by arable crop farmers to landowners adjust to ensure the equilibrium between their demand and landowner supply.

In this sensitivity analysis, we assume that the land supply to arable crop activities is perfectly price elastic and that the landowner believes that farmers may offer for the current year a moving average of previous land returns. In other words, landowners anticipate that arable crop farmers are able to pay previous land rents and if not, they will allocate their lands to other activities. This assumption intends to capture some regulations existing on land leasing in some countries (like France) where unit land rents are computed using past prices rather than as an equilibrium.

Results for the European coarse grains market are reported in figure 9. Again we find a diverging dynamic system and the resolution of the system stops seven years after the trade liberalisation shock. The intuition of this result is similar to the one we just identify with investment. By 'fixing' land returns, supply curves do not shift, leading to diverging cobweb. By contrast, once we allow the current land returns to adjust, then the supply curve shifts outwards in case of expected price decrease (and conversely). This prevents the divergence of the dynamic system.

(Insert figure 9)

The modelling implication is again that a CGE setting reveals more adjustment mechanism. From a policy perspective, this result suggests that some badly designed public interventions may indeed prevent optimal adjustment of the markets, leading to crazy endogenous market fluctuations.

v/ Sensitivity to substitution elasticities

When we adopt extreme expectation schemes and remove some market adjustments (on investment, land returns), we encounter cases of diverging cobwebs. It is well know that this divergence mostly depends on the ratio of supply and demand elasticities. In a CGE model, supply elasticities derive from assumptions on substitution elasticities and the mobility of factors. We have already seen that moving from a static to a dynamic rational expectation model, where capital is fixed per period, slightly reduces the price elasticity of supply (see section 5.2). With our imperfect expectation standard framework, short run supply elasticities are also lower because we further take into account the limited mobility of land. This still remains quite high compared to standard values used in agricultural partial equilibrium models. For instance, the European price elasticity of wheat equals 2.9.

In a last experiment, we reduce by half the substitution elasticities implemented in European arable crop technologies (the substitution elasticity between production factors and intermediate inputs). So the ex ante supply price elasticities also decrease by half (to 1.5 for European wheat production). Figure 10 reports the evolution of wheat price and production with standard and reduced elasticities. In this figure, we assume that alpha equals one half in order to better show the impacts. As expected, this reduces the price and quantity fluctuations and also the occurrence of diverging cobweb. This is in sharp contrast with static models where, once we reduce supply elasticities, we usually get larger price effects and lower quantity effects. Here we get both reduced price and quantity effects. The implication of this last result is that the endogenous fluctuations of price and quantity do not increase by lowering supply elasticities to standard values.

(Insert figure 10).

Conclusions

Most of the CGE models used today to assess the effects of agricultural policies are static or are said to be dynamic but they don't really take the inter-temporal decisions (investment, savings) of economic agents into account. To our knowledge, these agricultural policies have not been analysed with consistent dynamic CGE models and various expectation schemes. The nature of expectation schemes by farmers and more generally by all economic agents has already been extensively discussed in the economic literature. The rational expectation assumption is widely used for its consistency with other modelling

specifications but does not recognize the costs associated with the collection and the processing of market information. If this information is too costly, then agents may have simpler expectation scheme, possibly leading to diverging cobweb model. This endogeneity of market risk is one argument often mentioned in favour of a public intervention to stabilize agricultural markets. In light of policy debates on agricultural trade liberalisation, it is thus crucial to know if, by introducing dynamics and expectations in the CGE models used to assess agricultural policies, we end up with significant endogenous market risks or if the static results are quite robust to these specifications.

In that objective, we start from the usual static CGE approach and build dynamic CGE models with rational and imperfect expectations. We assess a complete agricultural trade liberalisation scenario by developed countries. What comes out of these simulations is that the dynamic model with rational expectations leads the same results as the static model: markets evolve linearly toward a steady state which corresponds to the static situation after the shock. On the other hand under the imperfect expectations assumption our trade policy scenario leads to endogenous market fluctuations. These fluctuations are all the more important that expectations take account of few past information and can even become higher and higher with time which leads to diverging dynamic systems if expectations are naïve. However the occurrence of divergence and the extent of endogenous fluctuations are seriously reduced with less extreme expectation schemes and more reasonable calibration of supply elasticities. Our CGE approach also reveals that many feedback effects, from competing sectors, from investment decisions and from (land) variable input markets, also reduce the occurrence and extent of endogenous market fluctuations generated from imperfect expectations. In other words, even if information is costly and agents form imperfect expectations, the consequences of these "bad" decisions are absorbed through the adjustment of the many related markets.

We are quite reluctant to draw too general policy recommendations from these results because the developed models still rest on simplifying assumptions. For instance, we assume perfect financial capital markets, we exclude risk aversion of economic agents, we focus the analysis on arable crop markets only, we omit the possibly smoothing role of storage, the existence of exogenous risks and of some policy instruments (public stocks for instance). All these extensions undoubtedly constitute an interesting and promising research agenda. In the meantime, our results give some interesting clues to the current agricultural policy debate. Static market effects simulated by current models are rather robust to the dynamic modelling of agricultural policies and to most expectation schemes. Endogenous market fluctuations do exist but are limited through many feedback effects. All agricultural policy design, should it finally be direct market intervention or more simply the provision of information, should acknowledge the existence of these tempering effects.

Table 1. Impacts of agricultural trade liberalisation from the static CGE model (in per cent with respect to the initial 2001 point).

	European Union		United States		Rest of the World	
	Production	Price	Production	Price	Production	Price
Wheat	-6.0	-0.9	0.9	0.3	0.7	0.2
Coarse grains	-6.9	-1.0	0.6	0.2	0.7	0.2
Oilseeds	0.6	-0.3	-0.2	0	0	0
Cattle	0.2	-0.4	-0.1	0.1	-0.1	0.1

Figure 1. Evolution of the European production and price of wheat under the rational expectation assumption (in per cent compared to the baseline)
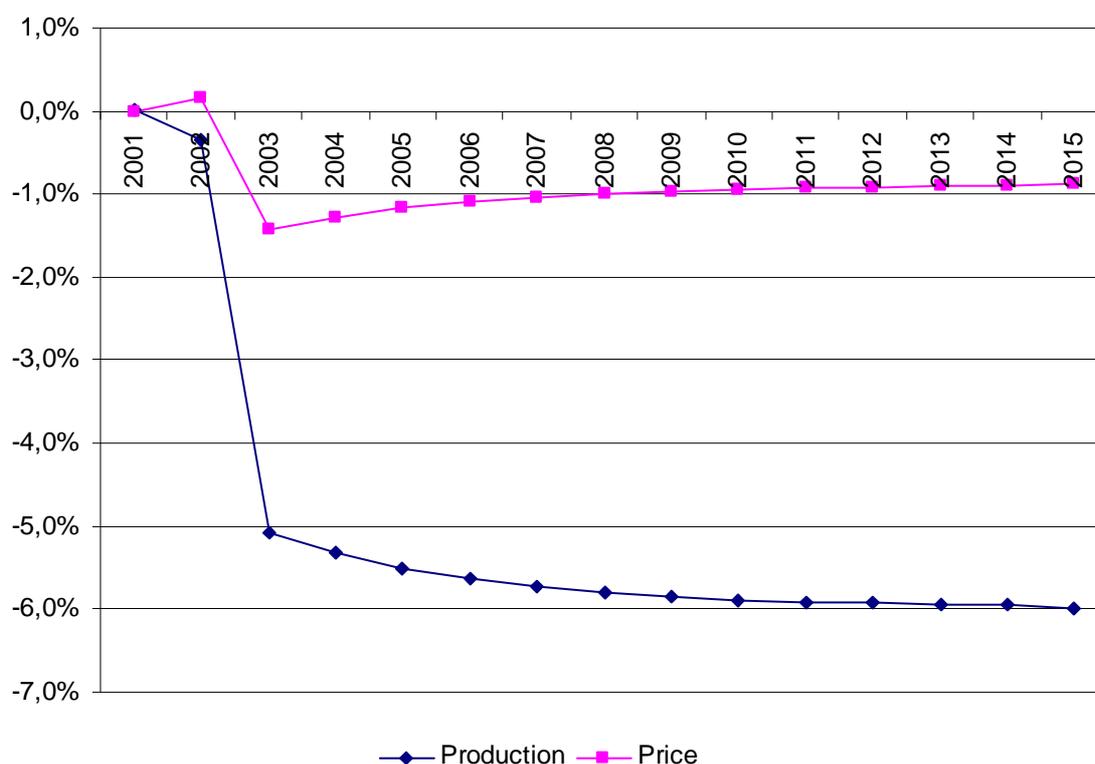
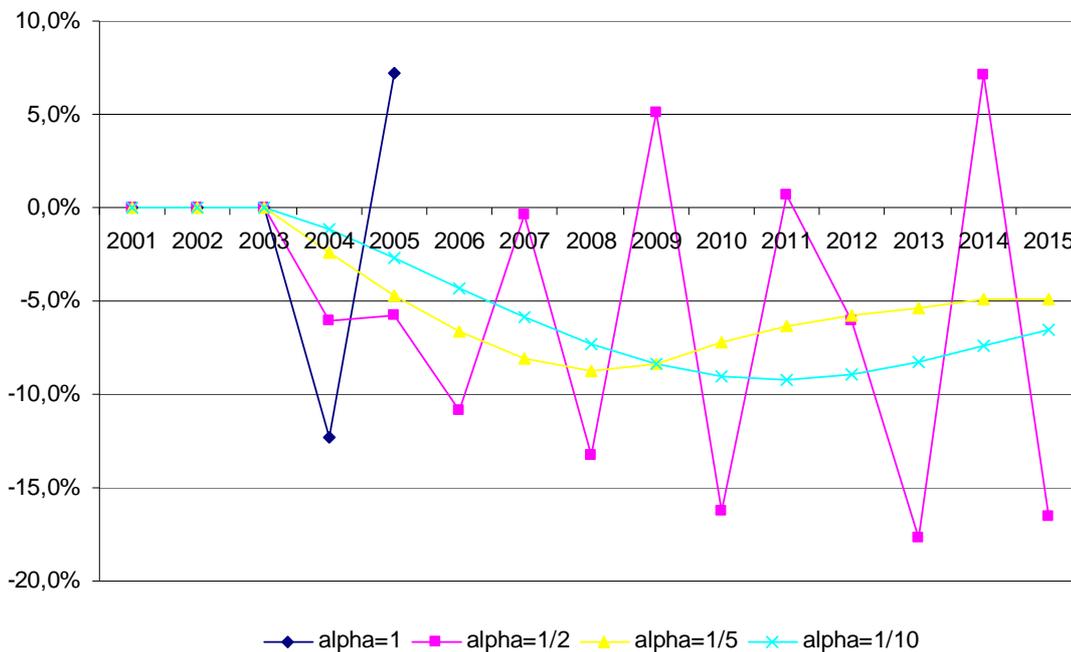**Figure 2. Evolution of the European production and price of wheat under the imperfect and rational expectation cases (in per cent compared to the baseline)**
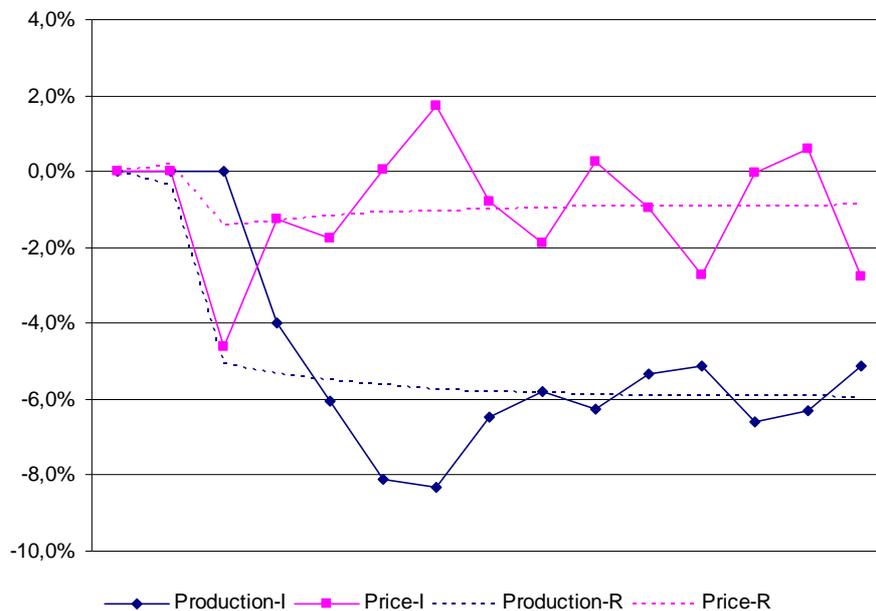
Figure 3. Evolution of the European production and price of coarse grains under the imperfect and rational expectation cases (in per cent compared to the baseline)
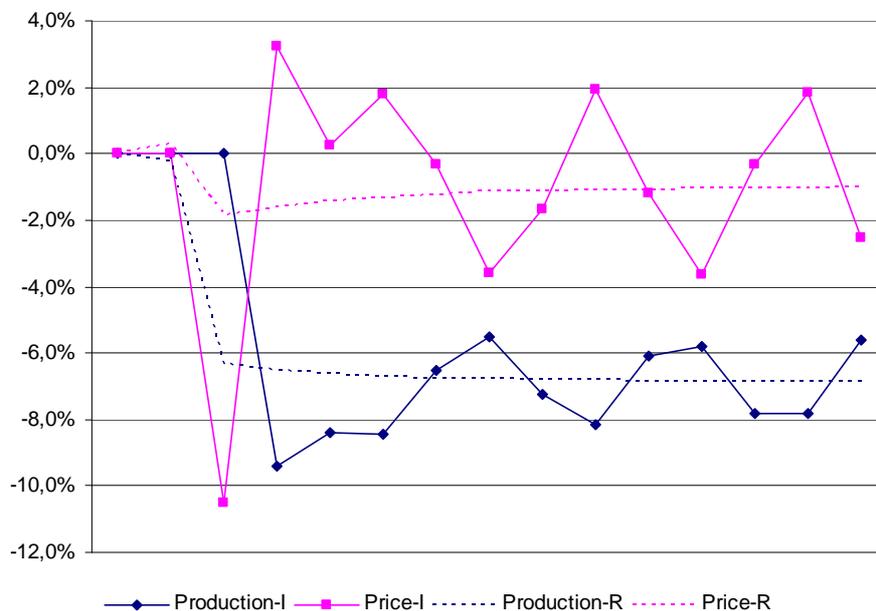
Figure 4. Evolution of the European production of wheat under the different imperfect expectations assumptions (in per cent compared to the baseline)
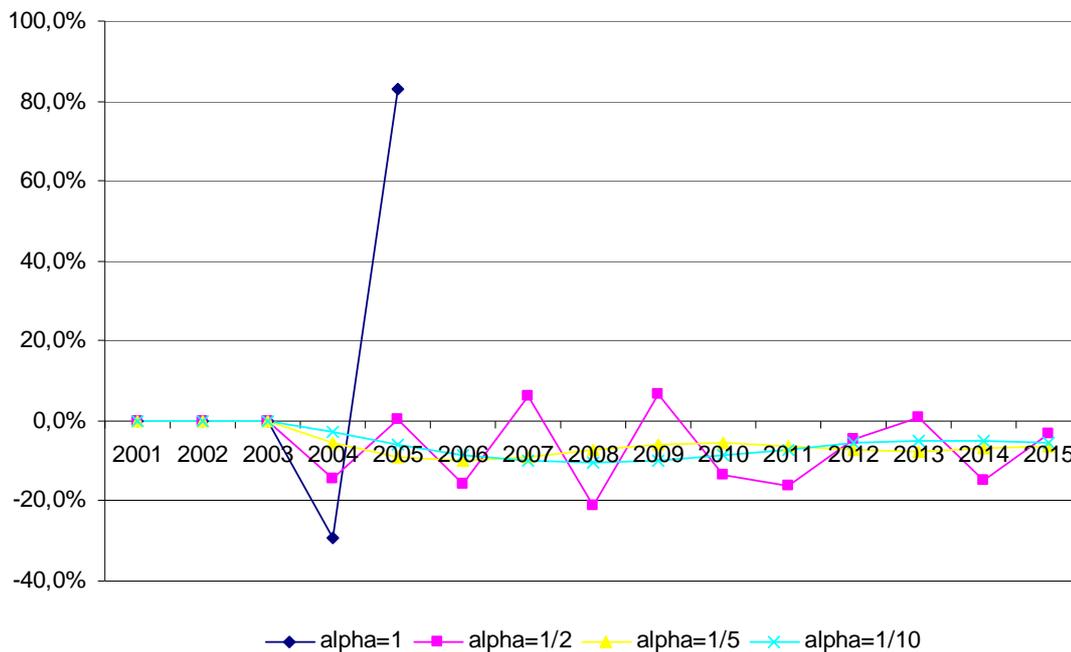

Figure 5. Evolution of the European price of wheat under the different imperfect expectations assumptions (in per cent compared to the baseline)
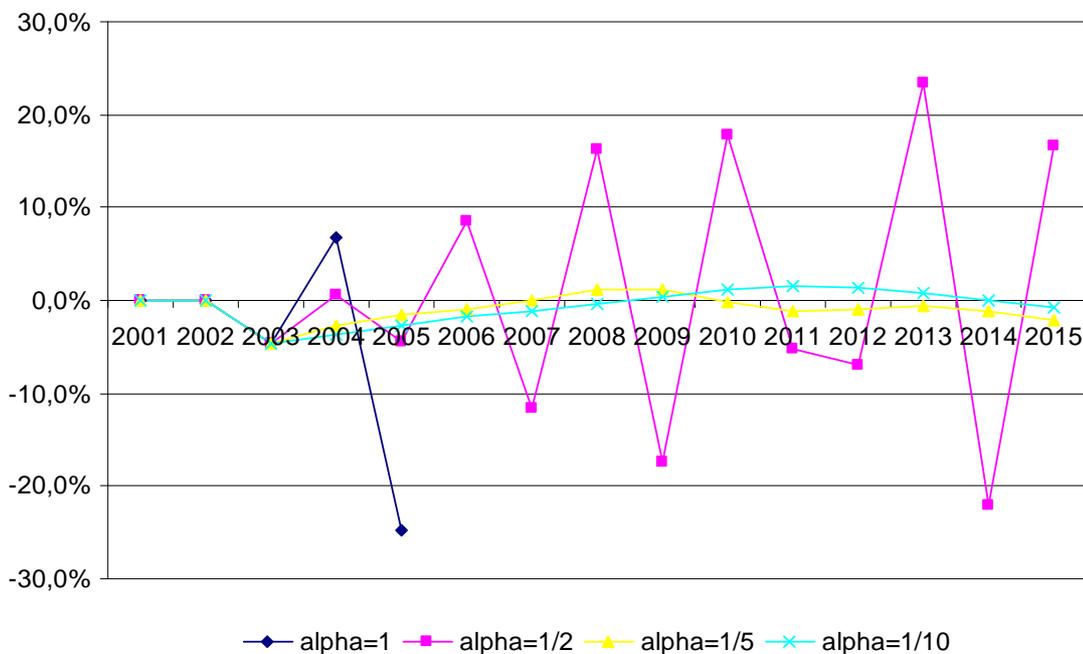
Figure 6. Evolution of the European production of coarse grains under the different imperfect expectations assumptions (in per cent compared to the baseline)

Figure 7. Evolution of the European price of coarse grains under the different imperfect expectations assumptions (in per cent compared to the baseline)
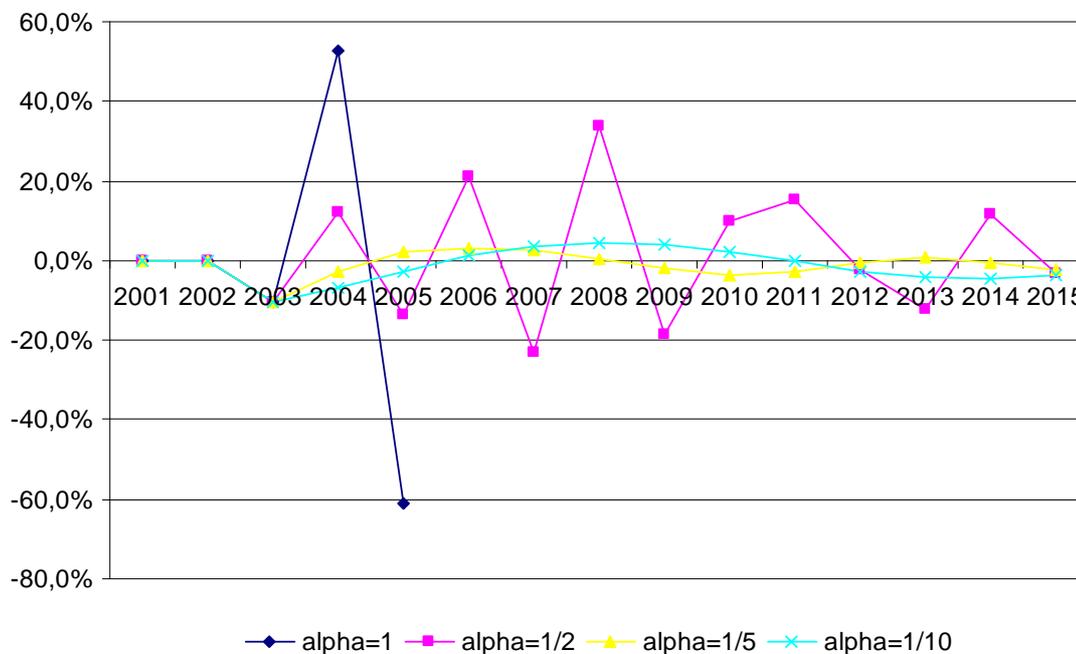
Figure 8. Evolution of the European production and price of wheat under the imperfect expectation case with fixed investment (in per cent compared to the baseline)


Figure 9. Evolution of the European production and price of coarse grains under the imperfect expectation case with "fixed" land returns (in per cent compared to the baseline)
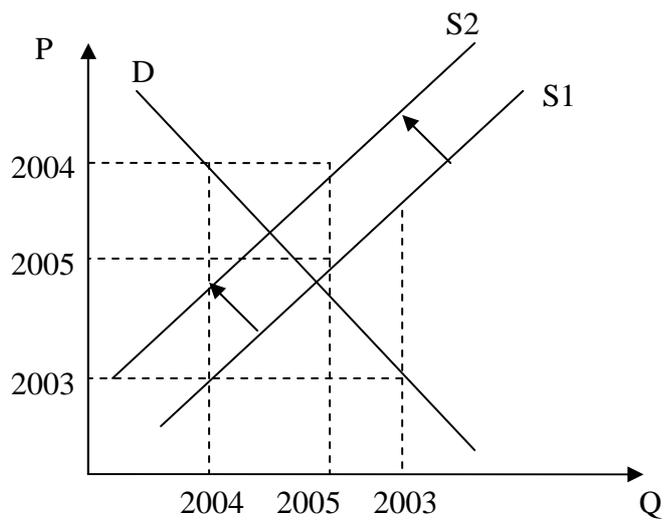
Figure 10. Sensitivity to supply elasticities of the evolution of the European production and price of wheat under the imperfect expectation case (in per cent compared to the baseline)
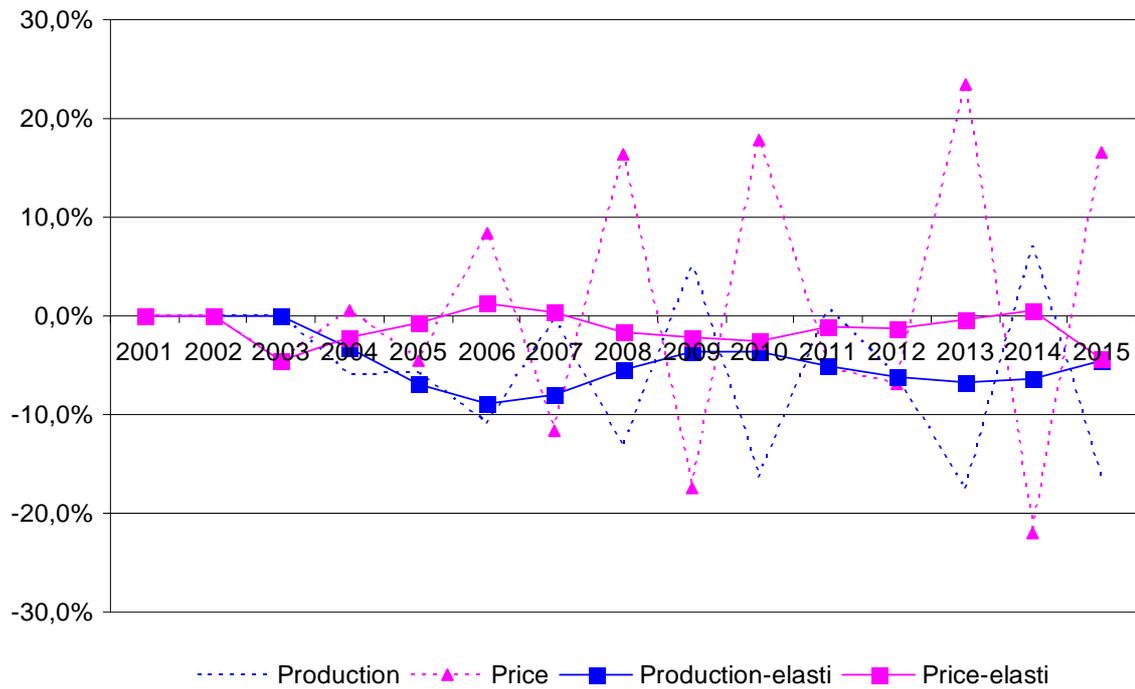
Graphic 1: The market dynamic without investment changes
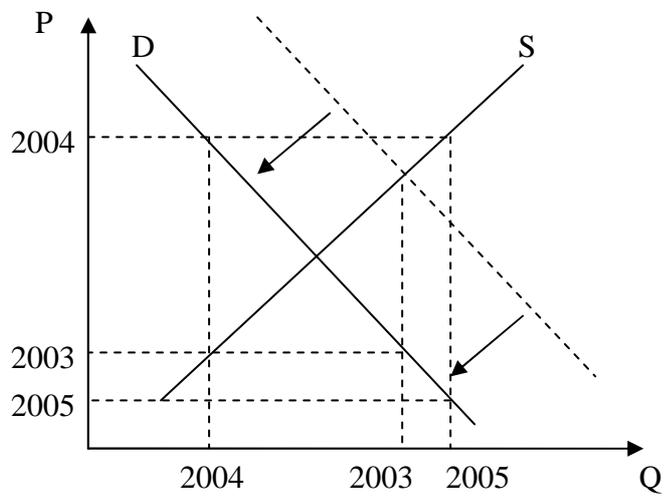
Graphic 2: The market dynamic with investment changes

Appendix A.

The purpose of this appendix is to show that world investment automatically equals world saving if agents are fully rational. Plugging equations R18 and S16 in R15, we obtain:

$$E_{rt} = D_{rt+1} - D_{rt} + \sum_i WL_{irt} L_{irt} + WK_{irt} K_{irt} + WT_{irt} T_{irt} + (1 + tm_{irt}) PWM_{irt} M_{irt}$$

Using equations S4 and S11, the right hand term simplifies to:

$$E_{rt} = D_{rt+1} - D_{rt} + \sum_i P_{irt} Y_{irt} + P_{irt} M_{irt}$$

Next we use R13 and S12 to get:

$$S_{rt} + \sum_i P_{irt} Q_{irt} = D_{rt+1} - D_{rt} + \sum_i P_{irt} Q_{irt} + P_{irt} I_{irt}$$

Dropping consumption expenditure, this equation simply states that domestic saving equal domestic investment plus net investment in foreign countries. At the world level, total foreign assets/debts vanish, so we finally get:

$$\sum_r S_{rt} = S_t = \sum_r \sum_i P_{irt} I_{irt} = I_t$$

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