Assessing the Market Impacts of the Common Agricultural Policy: Does Farmers' Risk Attitude Matter?

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Abstract

Recent models assessing the market impacts of Common Agricultural Policy (CAP) reforms are mostly static, non-stochastic and do not account for the risk attitude of farmers. This paper is a first attempt to fill this gap. We develop a stochastic version of GTAP-AGR model in which we introduce exogenous productivity shocks and farmers' attitude towards risks. In addition to the expectation on mean price, the expectation on price volatility also becomes one of the key factors for the farmers' decisions through its influence on risk premium. We show that under the endogenous modelling of the CAP instruments, risk aversion leads to larger production and price effects. The impacts are even larger if wealth effect is taken into consideration.

Keywords: Agricultural policy, Risk aversion, Stochastic, Dynamic, Computable general equilibrium, Partial equilibrium

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1 Introduction

The Common Agricultural Policy (CAP) of the European Union (EU) is a complex public policy pursuing different objectives with many instruments. This policy has a long history and has been reformed several times in the last two decades. Basically these reforms gradually reduce the initial market price support system and introduce payments intended to deal directly with potential market failures (public goods and bads, missing contingent markets and unfair competition) and to directly support farm income. The CAP instruments are now classified in two pillars, the first pillar including mostly market price instruments and direct payments and the second pillar mostly agri-environmental, rural development and risk management instruments.

Many ex ante assessments of the economic and physical impacts of these reforms (or proposals) have been performed either at the farm and/or market levels. This paper focuses on the modeling frameworks that have been recently developed to assess the market impacts of the CAP. We can distinguish between Computable General Equilibrium (CGE) frameworks, Partial Equilibrium (PE) frameworks and finally some studies combining both frameworks. Recent assessments using GE frameworks include Boulanger and Philippidis (2015) who analyze scenarios of reductions of all CAP payments, Urban et al. (2014) who explore a complete removal of first pillar payments, Boysen et al. (2014) who simulate a complete removal of first pillar instruments and Espinosa et al. (2014) who concentrate on second pillar rural development instruments. Recent assessments using PE frameworks include Mittenzwei et al. (2014) who remove WTO green box payments, Deppermann et al. (2014) who analyze separately price instruments and direct payments and Renwick et al. 2013 who remove all first pillar instruments. Finally CAP assessments performed with both CGE and PE models include Pelikan et al. (2014) who focus on the greening conditions attached to first pillar direct payments and Schroeder et al. (2014) who focus on the second pillar instruments. In a general way, all these studies conclude that the market impacts of the price instruments are, in absolute terms, more important than those induced by the direct payments of the first pillar, when the latter are linked to the land factor. On the other hand, there is less confidence on the relative impacts of the more recent second pillar instruments.

All aforementioned studies recognize the challenges to model accurately the way CAP instruments really operate. These market CGE/PE models are well designed to capture the working of the price instruments. On the other hand, they rely on more disputed assumptions for the other CAP instruments. In particular, the important direct payments of the first pillar are often modeled through so called coupling factors. These factors intend to measure the impacts of payments which occur through economic mechanisms that are not explicitly considered in these market models. Mostly cited is the wealth effect provided by direct payments to risk averse farmers (Hennessy 1998). In fact these models are generally static and non-stochastic, preventing the explicit modeling of such economic mechanisms. This leads for instance Moro and Sckokai (2013) to call for the revision of these market models routinely run for policy analysis because the impact of direct payments is analyzed by means of arbitrary coupling factors. In the same vein, Heckelei (2014) argue that these models are weak on the dynamic and stochastic dimensions and that they need to be improved to remain policy relevant.

To our knowledge, there have been limited efforts to improve the PE/CGE models devoted to analyze agricultural policy issues in these two dimensions. As regards the stochastic one, if there are numerous studies assessing impacts under different market conditions (for instance on the CAP, Nolte et al. 2012), there are few studies that take into account the attitude of economic agents towards risks. Burfisher et al. (2000) assess with a static CGE model the impacts of direct payments in the Canada, US and Mexico. They specify exogenous risk premiums that act like a production tax. They found very limited impact of their policy scenarios. Gohin and Treguer (2010) assess with a stochastic static PE model the market impacts of the US biofuel programs. They assume first that farmers are risk neutral, second that they are risk averse. In that second case, the risk premium is endogenous to market conditions. These authors find that the market impacts of the US biofuel programs at the stochastic steady state are similar across the two versions, unless the downside risk aversion of farmers and the price skewness induced by the US farm policy are taken into account. As regards the dynamic dimension, Femenia and Gohin (2011) develop a dynamic version of the static GTAP-Agr CGE model (Keeney and Hertel 2005) to assess the market impacts of agricultural trade liberalization. These authors find for this policy scenario that the available static results are quite robust to most expectation assumptions that are required in a dynamic framework. When the price expectations are rational, then the dynamic results converge to the static ones. On the other hand, when the price expectations greatly depart from rationality due to informational failures, they are much different with possible chaotic dynamic results. This leads these authors to further argue that a gradual implementation of CAP reform is preferable to an abrupt implementation when economic agents suffer from imperfect information (Femenia and Gohin 2013). In the same vein, Boussard et al. (2006) compare two dynamic CGE models and also find major impacts of the expectation assumptions in a trade liberalization scenario. These three studies focus on the so-called endogenous risks arising from informational issues while ignoring the exogenous production risks (not directly linked to human actions such as yield risks from stochastic climate events).

Hence the impacts of modeling assumptions on results are case-specific. This statement from our literature review is not specific to the assessment of agricultural policy issues, it is rather the rule. For instance, in the climate change economics, Ackerman et al. (2013) find that the introduction of risk aversion is unimportant when defining the optimal climate policy, unless catastrophic risks are taken into account. In that context, our main objective in this paper is to investigate to what extent the simultaneous introduction of exogenous risks and farmers' attitude toward risk matters when assessing the market impacts of the CAP.

We start our investigation using the standard static approach without any risk considerations. We choose as the benchmark the CGE approach, essentially because it potentially encompasses more economic mechanisms than a PE model. We retain the GTAP-Agr specification using the latest GTAP database calibrated on the 2011 economic flows. Because a risky event is a future event, not a present or past one, the explicit introduction of exogenous risks and risk attitude requires first a dynamic dimension. Accordingly, our investigation then continues with the development of a dynamic version of the GTAP-AGR model. Here we follow the approach of Femenia and Gohin (2011), where exogenous production risks and farmers' attitude towards risks are excluded. As these authors show the importance of price expectation schemes, we will consider different expectation schemes. In the third step of our investigation, we introduce exogenous production risks and farmers' attitude towards risks. The development of these different versions will allow us to reveal if the introduction of exogenous risks and farmers' attitude towards risks really matters when assessing the market impacts of some CAP instruments.

2 Modeling Frameworks

The different CAP reforms adopted in the last two decades have progressively changed the nature of policy instruments, with less emphasis on agricultural market price instruments and more emphasis on instruments targeting agricultural production factors and/or technologies (such as land payments, organic production). In order to assess the market impacts of this shift, the modeling frameworks offering an explicit representations of these factors and technologies become a priori more and more relevant. We indeed observe that the CGE framework, which naturally encompasses these features, is more and more prevalent for the assessment of the CAP. In fact many global CGE models have been developed in recent years to perform policy assessments (such as the GTAP, GTAP-Agr, GTAPEM, LEITAP-MAGNET, MIRAGE-AGRI). None of them explicitly introduce the stochastic dimension and are generally based on the predominant global GTAP database. With respect to the CAP assessment, these different models mostly differ in their elasticity calibration (with more or less complex production, utility and factor mobility specifications) and their CAP instrument representation (in particular with the shares of direct payments linked to different primary factors of production).

Here we start from the publicly available static GTAPinGAMS model developed by Rutherford (2006) that we modify to introduce the GTAP-Agr elasticities. The CAP instrument representation is directly given by the last GTAP database, in particular the allocation of direct payments to the different primary factor returns. We briefly document the production part of this static CGE model before explaining our subsequent modifications to introduce the dynamic and stochastic dimensions.

2.1 The Static GTAP-Agr CGE Model

The GTAP-Agr model is a static CGE model derived from the GTAP model and designed to better capture certain structural features of world agricultural markets and policies (essentially through better calibration of elasticities). The GTAP model is a relatively standard multi-region CGE model where consumers are assumed to maximize their utility, factor owners their revenue. This model employs the simplistic assumptions of perfect competition in all commodity and factor markets, that flexible prices ensure market equilibrium and that investment are saving driven. Commodities are differentiated by origin, allowing the modeling of bilateral international trade flows. This GTAP framework is implemented using data organized in Social Accounting Matrices (SAM) per region capturing economic flows during a given year and exogenous substitution/price/income elasticities.

At the farm supply side, it should be underlined that the modeled agent is not one farmer who may own different primary factors (capital and land in addition to his own human capital and labor force) and decide production variables. Rather the approach is activity-based with a distinction made between the different primary factor owners. More precisely, it is assumed that there is a representative land owner in each region who allocates each year his land asset over different farm and non-farm activities. This allocation depends on the land return provided by each activity and is technically implemented by (nested) Constant

Elasticity of Transformation (CET) mobility functions which captures in a synthetic way the heterogeneity of the land asset. In the same vein, there is a representative labor supplier (for both skilled and unskilled) in each region who allocates each year his labor force and human capital to different activities in response to their labor returns. This is the same logic for the representative physical capital owner, who can be a domestic or foreign household. The primary factor returns generated by the different activities are constrained by the market and policy environment and the technological relationships that link outputs to inputs and primary factors of production. These technologies are usually mono-product, exhibit constant returns to scale and are specified through nested Constant Elasticity of Substitution (CES) technologies defined over variable inputs (chemicals for instance) and primary factors of production.

This agricultural supply modeling based on activity is not specific to the CGE approach, it is also implemented in some PE model (for instance the CAPRI model developed at the University of Bonn). It exhibits desirable features, such as the use of activity-based input-output matrix that are compiled by national statistical institutions and incorporated in the SAM. It also exhibits some weakness, such as the requirements to measure all commodity uses and primary factor returns by all activities. This can be problematic when activities are highly detailed (such as the distinction of wheat and coarse grains in the cereal sector). Indeed this has long been recognized when trying to assess the market impacts of CAP direct payments (Jensen and Frandsen 2003).

More than this measurement issue, our main point in this paper is that this static activity-based supply modeling does not allow the explicit modeling of farmers' attitude towards risk. Farmers, and other producers as well, are not explicitly identified. They are indeed aggregated with other households and eventually only the aggregated attitude toward risks can be contemplated. Moreover, this static approach assumes that the regional households (more precisely primary factor owners) know the true market prices of commodities and the true primary factor returns when they decide their factor allocation. The lag between production decisions and commodity selling on market is not recognized, preventing the real modeling of the dynamic and stochastic dimensions. In order to authorize the later analysis of farmers' attitude towards risk on CAP assessments, we thus need to model farmers even in the static approach. The simplest way to do this is to assume that the physical capital initially allocated to each activity is specific to that activity and is owned by a representative producer who maximizes his primary factor return. This return will contribute to the income of the regional representative household. Indeed this assumption is also adopted by recursive dynamic models (such as Linkage or Mirage) and static CGE models as well when they want to compute short term effects (Keeney and Hertel 2009 for instance). The interpretation of the static CGE model is then the following. There is a representative producer in each activity who is the owner of the physical capital installed in that activity. This producer (farmer for an agricultural activity) maximizes his profit by choosing the optimal level of production, input use and factor use (possibly hiring labor and renting land) subject to his CES-based production technology. This profit will be added to the income of the regional household. Hence it is assumed that farmers have the same structure of preferences over consumption goods as other economic agents.

Mathematically, the following producer program is implemented for all farm activities in all regions:

$$\begin{aligned} \text{Max} \quad \pi(K_{ir}) =& (P_{y_{ir}} + t_{y_{ir}})Y_{ir} - (WT_{ir} - t_{t_{ir}})T_{ir} - (WS_{ir} - t_{sl_{ir}})SL_{ir} \\ & - (WU_{ir} - t_{ul_{ir}})UL_{ir} - \sum_j (WX_{jir} - t_{x_{jir}})X_{jir} + t_{k_{ir}}K_{ir} \\ s.t. \quad Y =& f(X_{jir}, T_{ir}, SL_{ir}, UL_{ir}, K_{ir}) \end{aligned} \tag{1}$$

where the index i and r stand for the activity i in region r, $\pi(K_{ir})$ is the profit, Y_{ir} is the output level, $P_{y_{ir}}$ is the output price, T_{ir} is the land use, WT_{ir} is the land rental price, SL_{ir} is the skilled labor input and WS_{ir} the respective price, UL_{ir} is the unskilled labor input and WU_{ir} the respective price, X_{jir} is the intermediate use of commodity j for activity i with WX_{jir} the corresponding prices and finally all t are net subsidies. In the following, P will be used for these prices/returns net of these subsidies to simplify the expressions.

In order to clarify the latter implementation of the version with risk aversion and its more intricate calibration/resolution, it is useful to detail the production technology and the calibration of specified parameters. It takes the following nested CES form:

$$Y_{ir} = \alpha_{y_{ir}} \left(\delta_{y_{ir}} Q_{va_{ir}}^{-\rho_{y_{ir}}} + (1 - \delta_{y_{ir}}) Q_{nva_{ir}}^{-\rho_{y_{ir}}} \right)^{-1/\rho_{y_{ir}}}$$

where $Q_{va_{ir}}$ is the quantity of value added bundle, $Q_{nva_{ir}}$ is the quantity of non value added bundle. These two aggregates are also defined by CES functions:

$$\begin{aligned} Q_{va_{ir}} &= \alpha_{q_{ir}} (\delta_{T_{ir}} T_{ir}^{-\rho_{qva_{ir}}} + \delta_{sl_{ir}} SL_{ir}^{-\rho_{qva_{ir}}} + \delta_{ul_{ir}} UL_{ir}^{-\rho_{qva_{ir}}} + \delta_{k_{ir}} K_{ir}^{-\rho_{qva_{ir}}})^{-1/\rho_{qva_{ir}}} \\ Q_{nva_{ir}} &= \alpha_{q_{nva_{ir}}} (\sum_j \delta_{x_{jir}} X_{jir}^{-\rho_{qnva_{ir}}})^{-1/\rho_{qnva_{ir}}} \end{aligned}$$

with $\quad \delta_{t_{ir}} + \delta_{sl_{ir}} + \delta_{ul_{ir}} + \delta_{k_{ir}} = 1, \quad \sum_j \delta_{x_{jir}} = 1$

The constant return to scale assumption greatly facilitates the resolution of this program and its implementation. This assumption ensures that the profit is given by the product between the capital stock and the unitary capital return, the latter being independent of the former:

$$\pi(K_{ir}) = P_{k_{ir}} K_{ir}$$

It is thus possible to solve this program and calibrate the numerous CES parameters as if the capital stock is endogenous and the unitary capital return is exogenous. When the optimal hicksian demand functions are introduced in the full CGE model, the capital stock is turned exogenous and the unitary capital return becomes endogenous and activity-specific. The optimal hicksian levels of variable inputs and primary factor uses are given by the following cost minimization program:

$$\begin{aligned} \text{Min} \quad & C(Y_{ir}, K_{ir}) = P_{t_{ir}} T_{ir} + P_{sl_{ir}} SL_{ir} + P_{ul_{ir}} UL_{ir} + \sum_j P_{x_{jir}} X_{jir} \\ & s.t. \quad Y_{ir} = f(X_{jir}, T_{ir}, SL_{ir}, UL_{ir}, K_{ir}) \end{aligned} \tag{2}$$

The hicksian demands are:

$$\begin{aligned} X_{jir} &= Q_{nva_{ir}} \alpha_{q_{nva_{ir}}}^{\sigma_{q_{nva_{ir}}}-1} \left(\frac{\delta_{x_{jir}} P_{nva_{ir}}}{P_{x_{jir}}} \right)^{\sigma_{q_{nva_{ir}}}} \\ SL_{ir} &= Q_{va_{ir}} \alpha_{q_{va_{ir}}}^{\sigma_{q_{va_{ir}}}-1} \left(\frac{\delta_{sl_{ir}} P_{va_{ir}}}{P_{sl_{ir}}} \right)^{\sigma_{q_{va_{ir}}}} \\ UL_{ir} &= Q_{va_{ir}} \alpha_{q_{va_{ir}}}^{\sigma_{q_{va_{ir}}}-1} \left(\frac{\delta_{ul_{ir}} P_{va_{ir}}}{P_{ul_{ir}}} \right)^{\sigma_{q_{va_{ir}}}} \\ T_{ir} &= Q_{va_{ir}} \alpha_{q_{va_{ir}}}^{\sigma_{q_{va_{ir}}}-1} \left(\frac{\delta_{t_{ir}} P_{va_{ir}}}{P_{t_{ir}}} \right)^{\sigma_{q_{va_{ir}}}} \\ K_{ir} &= Q_{va_{ir}} \alpha_{q_{va_{ir}}}^{\sigma_{q_{va_{ir}}}-1} \left(\frac{\delta_{k_{ir}} P_{va_{ir}}}{P_{k_{ir}}} \right)^{\sigma_{q_{va_{ir}}}} \end{aligned}$$

with

$$\begin{aligned} Q_{va_{ir}} &= Y_{ir} \alpha_{y_{ir}}^{\sigma_{y_{ir}}-1} \left(\frac{\delta_{y_{ir}} P_{y_{ir}}}{P_{va_{ir}}} \right)^{\sigma_{y_{ir}}} \\ Q_{nva_{ir}} &= Y_{ir} \alpha_{y_{ir}}^{\sigma_{y_{ir}}-1} \left(\frac{(1-\delta_{y_{ir}}) P_{y_{ir}}}{P_{nva_{ir}}} \right)^{\sigma_{y_{ir}}} \\ P_{nva_{ir}} Q_{nva_{ir}} &= \sum_j P_{x_{jir}} X_{jir} \end{aligned}$$

$$P_{va_{ir}} Q_{va_{ir}} = P_{t_{ir}} T_{ir} + P_{sl_{ir}} SL_{ir} + P_{UL_{ir}} UL_{ir} + P_{k_{ir}} K_{ir}$$

The optimal output level is implicitly determined by the introduction in the full CGE model of the zero profit condition. The concrete implementation of these functions requires the knowledge of substitution elasticities. The values of δ CES parameters are then determined using initial economic flows registered in the SAMs. For instance, we have:

$$\delta_{t_{ir}} = \frac{P_{t_{ir}} T_{ir}{}^{1/\sigma_{qva_{ir}}}}{P_{t_{ir}} T_{ir}{}^{1/\sigma_{qva_{ir}}} + P_{sl_{ir}} SL_{ir}{}^{1/\sigma_{qva_{ir}}} + P_{ul_{ir}} UL_{ir}{}^{1/\sigma_{qva_{ir}}} + P_{k_{ir}} K_{ir}{}^{1/\sigma_{qva_{ir}}}}$$

We also clarify for later versions the program of the representative land owner in each region. It is given by:

$$\text{Max} \quad R(T_r) = \sum_i R_{ir} T_{ir}$$
$$s.t. \quad T_r = CET(T_{ir})$$

We obtain the optimal land supply function in terms of market returns (different from net prices paid by farmers by the direct payments):

$$T_{ir} = T_{ir}^S(T_r, R_{jr}, R_{j'r})$$

The equilibrium between this land supply function and the previously land demand function determined by the farmer is obtained by the endogenous land rental price. It should be recognized here that the land market regulations are not explicitly represented (eventually very implicitly by the choice of the CET transformation elasticity).

2.2 The Development of a Dynamic Version

In most productive activities, inputs and/or primary factors of production are engaged before the production is realized. This is particularly true in farming where arable crop producers for instance first decide their land use and seed application, then apply variable inputs over the plant growing period such as fertilizers and pesticides and finally harvest the crop and market it (possibly directly selling on the market or storing before selling). This time lag between production decisions and production marketing implies that the farmers must base their decisions on expected prices, which can be different from true ones. By nature, this issue is neglected in static analysis while dynamic analyses generally conclude that the price expectations are critical.

There have been many debates about the precise nature of farmers' price expectations and more generally on expectation by economic agents (Manski 2004). This is a difficult empirical task, possibly more complicated in agriculture than in other productive sectors due to the existence of pervasive agricultural policies. The endogenous modeling of price expectations is in fact highly challenging. For instance, future markets provide some information about the market expectations at a given point of time about future prices, both their mean level and their volatility (option prices). These contingent markets exist for some commodities in some regions. Svaleryd and Vlachos (2002) find that there is a positive interdependence between the development of financial markets and trade liberalization. This finding is especially relevant in the EU agricultural context where some future markets have emerged following the CAP reforms and the decrease of market price support system. This suggests that the micro-structure of markets need to be endogenous to the contemplated policy scenarios. To our knowledge, this idea has never been introduced in dynamic models used for ex ante simulations. One possible reason is the predominant use of the rational expectation assumption which poses that economic agents, in the aggregate, do not suffer from informational issues. This assumption is highly convenient as it avoids identifying the information gathered and processed by each economic agent. Just and Rausser (2002) develop a theoretical analysis showing that the relevance of the rational expectation assumption depends on the costs of information collection and process relative to their benefits. If the costs are high relative to the benefits, simple expectation schemes such as myopic, naïve one can be optimal.

Hence the modeling of dynamic behavior is a tricky issue involving unobservable expectations and used information by economic agents. In this paper, we adopt backward price expectation schemes. That is, we assume that farmers form their price expectations using past observations, with different weights attached to recent versus old observations. Two main arguments support our assumption. The first argument is computational. The alternative rational expectation assumption implies a forward looking behavior where economic agents, including farmers, are assumed to solve the full CGE model for all future years. Even when we ignore the volatility dimension, the resolution of a highly detailed forward-looking CGE model with endogenous regime (active vs non active market price support regime) is a computational challenge. To our knowledge, available software to solve Dynamic and Stochastic General Equilibrium (DSGE) models (such as the Dynare) are more and more powerful allowing richer specifications and many state variables. However they presently remain highly sensitive when discontinuities are introduced in the models. The second argument is that we want to assess the market impacts of the CAP not only at the stochastic steady states but also during the transition period between two stochastic steady states. It is generally more accepted that the rational expectation assumption fits better in the long run that in the short run. In other words, there may exist some learning periods where economic agents progressively update their beliefs/expectations before reaching a new stochastic steady state induced by the policy scenario.

In addition to the expectation assumptions, we also need for the implementation of the dynamic version to decide the number of periods we consider during a given year (such as the planting period, the application period of fertilizers, pesticides, the harvesting period,...) and the predetermined versus endogenous variables in each period. We again adopt simplest assumptions by dividing a year in two periods. In the first period that can be labeled the production period, farmers equipped with their physical capital decide their production, input and primary factor levels given their commodity price expectations and also the labor price expectations (labor is used all along the production campaign, such as during harvesting). On the other hand, the land use is negotiated at the beginning of the production campaign with the land owner. This economic agent needs to form land return expectations for other potential activities when deciding to allocate some land to one farming activity. Hence in the first period of a given year, we determine the output level, input use, primary factor use (land and labor) by the farmers, parts of the land allocation by the land owner and the equilibrium land return for these dynamic activities. In the second period of the given year that can be labeled the marketing period, these variables become predetermined in the static CGE model, market price will be determined, residual capital return as well. They may differ from expected values by farmers.

Mathematically, the program solved by the producer in the first period of each year (indexed by t) is:

$$\begin{aligned} \text{Max} \quad E(\pi(K_{irt})) =& E(P_{y_{irt}})Y_{irt} - P_{t_{irt}}T_{irt} - E(P_{slirt})SL_{irt} \\ & - E(P_{ulirt})UL_{irt} - \sum_j E(P_{x_{jirt}})X_{jirt} \\ s.t. \quad Y_{irt} =& f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt}) \end{aligned} \tag{3}$$

This program is very similar to the program (1) defined before. The only difference comes from the formulation of expected prices/returns in place of realized prices/returns. The resulting hicksian demand are thus of the same nature. The program of the representative land owner is also changed in the same spirit, with expected land returns rather than realized ones expect for the dynamic activities. Formally, the representative land ower solves a first program in the first period of each year. This program is:

$$\begin{aligned} &\mathrm{M}ax \sum_i E(R_{irt}) T_{irt} \\ &s.t. \quad T_{rt} = CET(T_{irt}) \\ &s.t. \quad E(R_{irt}) = R_{irt} \end{aligned}$$

We thus define a PE model in the first period, made of the optimal decisions of farmers and land allocation by land owners. This PE model determines in particular the land returns for the dynamic farm activities and their optimal supplies, variable input and primary factor uses. In order to solve this model, we must assume the exact price expectations made by farmers (and landowners). The economic flows reported in the SAM do not indicate whether the realized capital return is exactly the anticipated one by farmers. We simplify again the analysis in this paper assuming that the initial situation reported in the SAM is a steady state and that economic agents did not make price expectation errors in that year.

The results of this first period PE model are fed into the full CGE model, where the relevant variables are now turned to exogenous ones and corresponding equations are removed. In this modified CGE model, the representative land owner still allocate the remaining land to the different activities.

It remains us to determine the dynamic over the years. The exogenous variables in the first period PE model are the capital stocks and the net price expectations. We need to determine the dynamics of these exogenous variables. We again make simplified assumptions by assuming that the capital stock in each farm activity is always the same. This implies that the sectoral investment in the full CGE model solved in the preceding year is assumed to equal the exogenous depreciation. We recognize that this assumption restricts our analysis by potentially excluding some risk management strategies pursued by farmers. In particular, they may delay or advance their investments following unexpected price realizations. As far as we know, available econometric studies assessing the farmer' risk aversion mostly ignore these possibilities. So our latter development of the volatility version with risk aversion is consistent with this assumption. The only inter-year dynamics occur in our analysis by the revision of the net price expectations. As mentioned earlier, we assume that the price expectation made by farmers for future periods take into account past observations, including the last computed one. In case of the product price, this means that:

$$E(p_{y_{ir,t+1}}) = (1-\alpha_p)E(p_{y_{irt}}) + \alpha_p p_{y_{irt}}, \quad 0 < \alpha_p < 1 \tag{4}$$

In a sensitivity analysis, we can vary the α_p parameter, allowing the implementation of static, myopic and adaptive price expectations.

To sum up this dynamic version, it represents the minimal departure from the previous static CGE framework. It is made of two models, one PE focused on the dynamic activities and one full CGE. The dynamic is recursive, we obtain a succession of temporary equilibrium. The dynamic over years is accomplished with only one type of variables, the expected prices/factor returns.

2.3 The Development of a Stochastic Version

The agricultural activity is confronted to many sources of risks, the most obvious one being the yield risk linked to climate events for crop activities. These production risks may lead to price risks, depending on the functioning of agricultural markets. Some European farmers have long been protected from these price risks with the market price instruments of the CAP. If the presence of production/price risks is not disputed, the exact attitude of farmers towards these risks is more debated. Many efforts have been pursued in recent years with different methods to reveal their risk attitude (Roe 2015). This is challenging for instance because one must also identify their expectations. It is still rather accepted that farmers in general, EU farmers as well, can be risk averse. This means that they prefer to crop a safe crop rather than a risky crop giving the same expected return. Our development of a stochastic version intends to capture these features.

We again do that in a simplified manner starting from the above dynamic version. For instance we maintain the specification of production technologies with nested CES functions and thus do not explicitly recognize the potential roles of some variable inputs (fertilizers is generally considered as risk increasing and pesticides risk decreasing). Capturing these roles requires a new specification of the production technology, such as the "Just and Pope" one. Rather we will follow previous examples (van Meijl and van Tongeren 2002) by assuming multiplicative production risks in non-european regions. Formally, we assume that the production parameters $\alpha_{y_{ir}}$ are stochastic and thus take different values (explained later). At the second period of each year, we solve the full CGE model with these different values, leading to different world and european prices for agricultural commodities.

Turning to the first period of the following year, we assume that EU farmers consider only their output price as a stochastic variable, that they maximize the expected utility of their profit and that their utility function exhibits Constant Absolute Risk Aversion (CARA). Formally, the farmer's decision problem is:

$$\begin{aligned} \text{Max} \quad EU(\pi(K_{irt})) =& EU(P_{y_{irt}} Y_{irt} - P_{t_{irt}} T_{irt} - P_{sl_{irt}} SL_{irt} \\ & - P_{ul_{irt}} UL_{irt} - \sum_j P_{x_{jirt}} X_{jirt}) \\ s.t. \quad Y_{irt} =& f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt}) \end{aligned} \tag{5}$$

This expected utility program can be rewritten as a mean-variance program if we furthermore assume that the stochastic output price follows a normal law (a log normal assumption can be contemplated in an extension, while still specifying a mean variance approach, Chavas, 2004):

$$\begin{aligned} \text{Max} \quad EU(\pi(K_{irt})) =& E(P_{y_{irt}} Y_{irt} - P_{t_{irt}} T_{irt} - P_{sl_{irt}} SL_{irt} \\ & - P_{ul_{irt}} UL_{irt} - \sum_j P_{x_{jirt}} X_{jirt} - \frac{1}{2} \rho \sigma^2_{p_{y_{irt}}} Y^2_{irt}) \\ s.t. \quad Y_{irt} =& f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt}) \end{aligned} \tag{6}$$

The last term in the objective function is the risk premium and represent the amount of money that farmers are ready to forget in order to avoid risk. This risk premium is given by the product of the absolute risk aversion parameter (ρ), the expected variance of output prices and the square of the production level. As expected, the higher level of risk aversion, the higher the price volatility, the higher amount of money the farmer is ready to give up in order to avoid the price risk.

Compared to the previous farmer program, this new program involves the expected variance of output price. That is, we now need to define the average output price expected by farmers as well as their variance. An exceptional price last year may lead farmers to revise their price expectation and to consider that they will be more volatile in the future years. Or they may simply disregard it and consider that the volatility of output price is constant. As already underlined, it is difficult to know these expectations, even if option prices negotiated on future markets may reveal some information. Like the expectation on the average price, we will consider different expectation for the variance of output price:

$$E(\sigma^2_{p_{y_{ir,t+1}}}) = (1-\alpha_\sigma)E(\sigma^2_{p_{y_{irt}}}) + \alpha_\sigma \sigma^2_{p_{y_{irt}}}, \quad 0 < \alpha_\sigma < 1 \tag{7}$$

The resolution of this program can be decomposed in two steps. In the first step, the production costs are minimized, leading to the optimal hicksian demand and the optimal cost function. This is similar to the static case. In the second step, the expected utility (the weighted mean-variance) is then maximized by choosing the optimal production level. The corresponding program is:

$$\text{Max} \quad EU(\pi(K_{irt})) = E(P_{y_{irt}} Y_{irt} - C(Y_{irt}, K_{irt}) - \frac{1}{2}\rho\sigma^2_{p_{y_{irt}}} Y^2_{irt}) \tag{8}$$

The first order condition implicitly determines the optimal output level:

$$Cm(Y_{irt}, K_{irt}) = E(P_{y_{irt}}) - \rho\sigma^2_{p_{y_{irt}}} Y_{irt} \tag{9}$$

This equation states that the marginal cost at the optimal output level is equal to the expected price minus the marginal risk premium. The implementation/calibration of this program is more complicated than in the static case detailed before. Even if we maintain the constant return to scale assumption, the profit computed as the difference between receipt and variable expenditures does not equate the return to capital services. It also includes the risk premium. It should be acknowledged that the risk premium is not paid to a third party and does not appear in the SAMs because we do not consider contingent markets. We thus need to assume this value and will consider different initial values based on a literature review. More exactly we will assume different risk premiums in percentage of the market receipt:

$$\beta_{ir} = \frac{0.5\rho\sigma^2_{p_{y_{irt}}} Y_{irt}}{E(P_{y_{irt}})Y_{irt}} \tag{10}$$

In other words, we will assume in the calibration part the value of the product of the risk aversion parameter and the expected price variances by farmers and thus the initial marginal cost level. In order to solve and calibrate the cost minimization program, it is no longer possible to use the previous trick, that is the exogenous unitary capital return. The profit is no longer a simple expression of the capital stock multiplied by an unitary and exogenous capital return. The resolution/calibration of this cost minimization program leads to a system of first order conditions that is non linear in the parameters and the variables. It is no longer possible to get closed form solutions for the optimal input/factor demands. It is equally impossible to get closed form expressions to calibrate the technological parameters. Accordingly we will need to solve a system of first order condition to calibrate the technological parameters and not simply compute them as in the expressions (2.1) before. This system is:

$$\begin{aligned} \text{Min} \quad C(Y_{irt}, K_{irt}) =& P_{t_{irt}} T_{irt} + P_{sl_{irt}} SL_{irt} + P_{ul_{irt}} UL_{irt} + \sum_j P_{x_{jirt}} X_{jirt} \\ s.t. \quad Y_{irt} =& f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt}) \end{aligned} \tag{11}$$

The Lagrangian of this system is,

$$\begin{aligned} L(T_{irt}, SL_{irt}, UL_{irt}, X_{jirt}, \lambda) =& P_{t_{irt}} T_{irt} + P_{sl_{irt}} SL_{irt} + P_{ul_{irt}} UL_{irt} + \sum_j P_{x_{jirt}} X_{jirt} \\ &+ \lambda (Y_{irt} - f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt})) \end{aligned} \tag{12}$$

The first order conditions of the Lagrangean are given as:

$$P_{t_{irt}} - \lambda \frac{\partial Y_{irt}}{\partial T_{irt}} = 0 \tag{13a}$$

$$P_{sk_{irt}} - \lambda \frac{\partial Y_{irt}}{\partial SK_{irt}} = 0 \tag{13b}$$

$$P_{ul_{irt}} - \lambda \frac{\partial Y_{irt}}{\partial UL_{irt}} = 0 \tag{13c}$$

$$P_{x_{jirt}} - \lambda \frac{\partial Y_{irt}}{\partial X_{jirt}} = 0 \tag{13d}$$

$$Y_{irt} - f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt}) = 0 \tag{13e}$$

The Lagrange multiplier λ is the marginal cost when the minimization program is optimized. Taken into account condition (9), λ equals the expected price minus the marginal risk premium at the optimal output level:

$$\lambda = \frac{\partial C}{\partial Y} = E(P_{y_{irt}}) - \rho \sigma^2_{p_{y_{irt}}} Y_{irt} \tag{14}$$

By substituting eq.(14) into the first order condition set (13), the detailed first order conditions are finally presented as,

$$P_{t_{irt}} - (E(P_{y_{irt}}) - \rho \sigma^2_{p_{y_{irt}}} Y_{irt}) \cdot A \cdot \delta_{t_{irt}} T_{irt}^{-\rho_{qva_{irt}}-1} = 0 \tag{15a}$$

$$P_{sl_{irt}} - (E(P_{y_{irt}}) - \rho \sigma^2_{p_{y_{irt}}} Y_{irt}) \cdot A \cdot \delta_{sl_{irt}} SL_{irt}^{-\rho_{qva_{irt}}-1} = 0 \tag{15b}$$

$$P_{ul_{irt}} - (E(P_{y_{irt}}) - \rho\sigma^2_{p_{y_{irt}}} Y_{irt}) \cdot A \cdot \delta_{ul_{irt}} UL_{irt}^{-\rho_{qva_{irt}}-1} = 0 \tag{15c}$$

$$P_{x_{jirt}} - (E(P_{y_{irt}}) - \rho\sigma^2_{p_{y_{irt}}} Y_{irt}) \cdot B \cdot \delta_{x_{jirt}} X_{jirt}^{-\rho_{qnva_{irt}}-1} = 0 \tag{15d}$$

$$Y_{irt} - f(X_{jirt}, T_{irt}, SL_{irt}, UL_{irt}, K_{irt}) = 0 \tag{15e}$$

where

$$A = \alpha_{y_{irt}} \delta_{y_{irt}} (\frac{Y_{irt}}{\alpha_{y_{irt}}})^{1+\rho_{y_{irt}}} Q_{va_{irt}}^{-\rho_{y_{irt}}-1} \cdot \alpha_{qva_{irt}} (\frac{Q_{va_{irt}}}{\alpha_{qva_{irt}}})^{1+\rho_{qva_{irt}}}$$

$$B = \alpha_{y_{irt}} \delta_{y_{irt}} (\frac{Y_{irt}}{\alpha_{y_{irt}}})^{1+\rho_{y_{irt}}} Q_{nva_{irt}}^{-\rho_{y_{irt}}-1} \cdot \alpha_{qnva_{irt}} (\frac{Q_{nva_{irt}}}{\alpha_{qnva_{irt}}})^{1+\rho_{qnva_{irt}}}$$

To sum up this stochastic version, it again represents the minimum departure from the previous dynamic (but certain) PE/CGE framework. We only introduce risk aversion for EU farmers who only adjust their production level and input uses to manage their price risks. These price risks originate from productivity shocks in non EU regions. We now simulate a succession of stochastic temporary equilibrium. The dynamic over years is accomplished with two types of variables, the expected mean prices/factor returns and the expected volatility of output prices.

3 Simulations

3.1 Empirical Assumption

We implement the different versions of models described above using the latest GTAP database, version 9 GTAP, of which the data is calibrated from 2011 economic flows. We aggregate the data to 26 commodities including 17 agricultural products, 5 regions including EU28, China, US, Argentina-Brazil-Uruguay(ABU) and Rest of the World (RoW). In both the dynamic and stochastic versions, we have the opportunity to choose the number of dynamic activities. We start by focusing on one crop (wheat), and later extend to other activities. In these two versions, the expectation schemes need to be determined.

The price expectations of the producers are formed based on past observed prices and past price expectations by the historical weighting parameter α, similarly, the volatility expectations are based on past volatilities and past volatility expectations (see eq.(4), eq.(7)). We start with the naïve expectation scheme by assuming $\alpha = 1$, that is, the price expectations of the producers are equal to the observed prices of last year, and the volatility expectation equals the average price volatility of last year. In the sensitivity analysis, the weighting parameter α is extended to other values. It should be noted that in the stochastic version, it is not possible to obtain one certain price since the prices are stochastic, so that we approximate the final observed price via Gaussian Quadrature given the distribution of the shocks. Accordingly, the standard deviation of the price is obtained from the distribution of the stochastic output price.

When implementing the stochastic version, we also need to make assumptions on the risk premium and the productivity shocks. On the calibration of the risk premium, we fix the baseline risk premium at 2% of the production value ($\beta = 2\%$), which implies an absolute risk aversion coefficient of 1.25 with regard to the baseline price volatility. Our choice of β is in accordance with Femenia et al. (2010) who use a risk premium at 2.1% of the market receipt.

We assume that the productivity shocks follow a stochastic Gaussian process with mean zero and a standard deviation of 0.1. The productivity shocks ϵ_{irt} consequently impact on the production parameter $\alpha_{y_{irt}}$ in an exponential form as follows,

$$\alpha_{y_{irt}} = \alpha_{y_0} e^{\epsilon_{irt}}, \quad with \quad \epsilon_{irt} \sim N(0, 0.1) \tag{16}$$

where α_{y_0} is the production parameter calibrated at the initial point. We assume that the shocks apply in US, China, ABU and RoW every year.

To test the relevance of our calibration assumptions, we simulate with the first period PE model the effects of a 1% expected price decrease and a 1% price volatility decrease on EU wheat production. We use the standard deviation of prices (σ) as the indicator for volatility. As is reported in Table 1, risk aversion leads to a higher price elasticity (1.42) compared to that without risk aversion (1.30). The intuition behind is that when we account for the farmers' risk attitude, the the return on fixed capital is lower while the risk premium is price sensitive (as it depends on the output volume).

As expected, the wheat supply is not sensitive to price volatility in the risk-neutral case, and is sensitive to price volatility when the producer is risk-averse. The estimated supply

Table 1: Percentage Impacts of a 1% Decrease of the Expected Price and of the Expected Volatility on EU Wheat Production

	Risk neutrality	Risk aversion
Expected Price	−1.30	−1.42
Expected Volatility (σ)	0	0.11

elasticity with respect to price volatility is -0.11. This is because when the producer exhibits constant absolute risk aversion (CARA), a decrease in price volatility results in a lower risk premium, and thus a lower share of profit corresponding to the risk premium compared to that corresponding to the return on fixed capital. To put it in another way, risk-averse producers allocate a lower proportion of the profit to avoid the risk since the price volatility decreases, in this way they produce more.

3.2 Policy Scenarios

We are now ready to analyze the market impacts of the CAP using our different versions of GTAP-Agr model. So far we did not explain the modeling of CAP instruments. In most CGE applications, the price instruments act through ad valorem export subsidies and import tariffs which are usually assumed to be exogenous. In reality the levels of these price instruments can be adapted to protect the domestic price from dropping below a price floor (the so-called intervention price) when the world price is low. Accordingly we will consider below two alternative modeling of the price instruments: either an exogenous representation where the unitary levels are fixed, either an endogenous representation where they adjust to ensure minimum intervention/entry prices. The modeling of direct payments is also challenging with the decoupling of farm payments introduced in 2003. These direct payments are perceived by farmers provided that they have a corresponding land use. Accordingly they are often modeled as an ad valorem subsidy to the land factor, while remaining coupled subsidies are linked to the production. Below we adopt the allocation of subsidies provided in the GTAP9 database and again consider two modeling. The standard exogenous one assumes that the unitary land payment is ad valorem (and thus change with the land return) while the endogenous one assumes that the unitary land payment are fixed per hectare. These two alternative modeling of CAP instruments are indeed worth differentiating with our stochastic framework.

We successively simulate two radical policy scenarios: first the EU removes the price instruments on wheat, second the EU removes the direct payments on wheat. In both scenarios, the policy instruments in other regions and on other farm products stay at their initial level. Very importantly, the impacts are assessed compared to a baseline. It should be understood that the baseline may change depending on the representation of the CAP. More specifically, in the static version and the dynamic version, we assume that the economy is initially at the steady state, and the initial point is used as the baseline. In the stochastic version, the introduction of productivity shocks makes the economy moves from the initial steady state to a new stochastic steady state, and this new stochastic steady state is used as the baseline in the stochastic model.

3.3 Simulation Results

3.3.1 Results from the Static GTAP-Agr Model

We concentrate our analysis on price, production in EU and RoW. Table 2 shows the impacts of the policy scenarios in the static GTAP-Agr model. We find that the EU wheat production declines by 1.98% in response to the removal of price instruments. This is because removing the trade barriers puts downward pressure on domestic EU wheat prices, which induces a 1.69% reduction in EU wheat price. On the contrary, the wheat production and price in rest of the world increase by 0.54% and 0.32% respectively since they benefit from less supply coming from Europe.

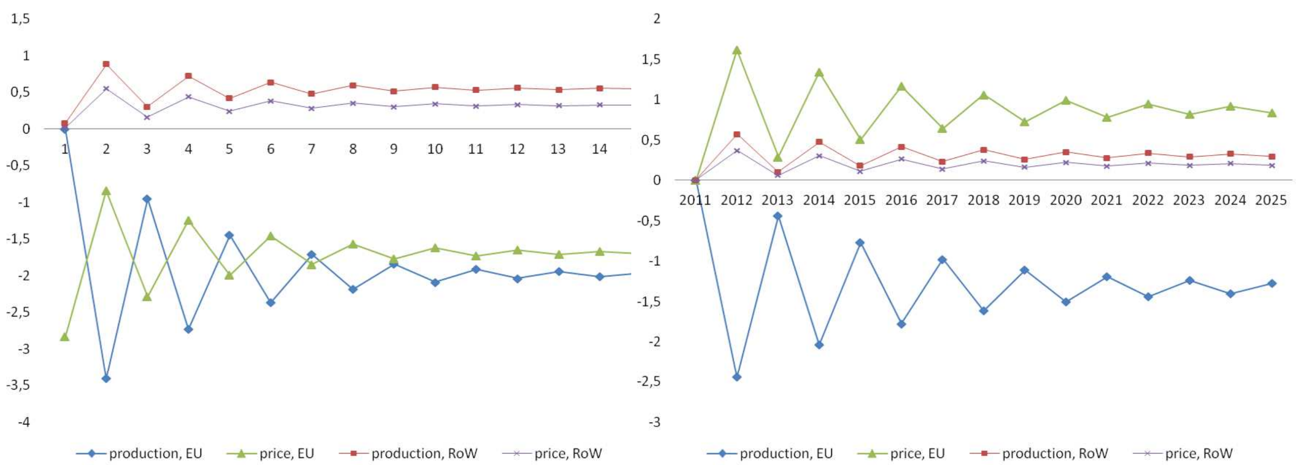
We also find that removing the direct payments induces a 1.29% decline in EU wheat production. As the direct payments are linked to the factor land, more acreages are thus allocated to other activities with higher land returns and less lands are used for wheat production. Accordingly the EU wheat production declines and the EU wheat price increases. Again the rest of the world faces less competition from Europe, as witnessed by the expanding of wheat production by 0.30% and the increase of wheat price by 0.19% in RoW. All these results are quite standard now and constitute our benchmark results before dealing with the dynamic and stochastic dimensions.

Table 2: Impacts of the Removal of Price Instruments and the Removal of Direct Payment on EU Wheat (in percent with respect to the initial baseline)

	European Union		**Rest of the World**	
Removal of Price Instruments	Production	Price	Production	Price
Static Model	-1.98	-1.69	0.54	0.32
Dynamic Model (Steady State)	-1.96	-1.70	0.54	0.32
Removal of Direct Payments	Production	Price	Production	Price
Static Model	-1.29	0.90	0.30	0.19
Dynamic Model (Steady State)	-1.28	0.84	0.30	0.19

3.3.2 Results from the Dynamic Version

Figure 1 depicts the evolution of EU wheat production and price after implementing the policy scenarios in 2011. After 15 years' evolution, the EU wheat production and price converge to a steady state, and the converged market impacts in the dynamic model are almost the same with the impacts in the static model (see table 2). This result is similar to Femenia and Gohin (2011) who find that the static results are robust to most expectation schemes and they are quite accurate for long run assessments. We found that even when the expectation scheme are naive, this radical scenario applied to wheat does not lead in the long run to diverging series. This is partly explained by the fact that the price elasticity of total demand of EU is quite large in absolute terms (at least according to the GTAP-Agr choice of elasticities).



(a) Removal of Price Instruments (b) Removal of Direct Payments

Figure 1: Evolution of the EU Wheat Production and Price under the Naïve Expectation Assumption in Dynamic Version (in percent compared to the initial baseline)

3.3.3 Results from the Stochastic Version with Exogenous Policy

We now use our stochastic version with the exogenous policy representation. Before assessing the policy impacts, it is important to obtain a new baseline because the economy has moved from the initial steady state (the baseline used in the static and dynamic version) to a new stochastic steady state due to the introduction of the stochastic productivity shocks. We perform thus a first stage simulation by including only the productivity shocks. We reach the new stochastic steady state after 30 years in the stochastic model without risk aversion

Table 3: Impacts of the Removal of CAP Instruments under Exogenous Policy Representation (production and price in percent with respect to the baseline)

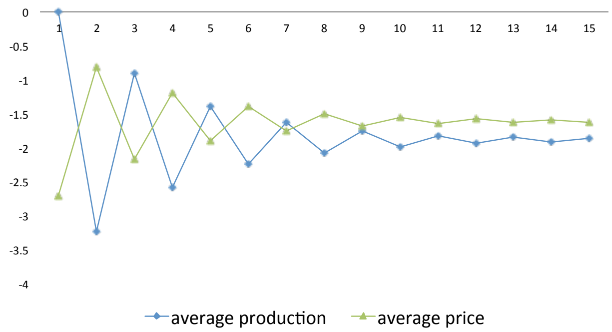
	European Union				**Rest of the World**		
	Production	Price	Volatility(σ)	β	Production	Price	Volatility(σ)
New Baseline with Productivity Shocks							
Risk Neutral	1.09	0.92	0.15	-	1.45	1.64	0.17
Risk Aversion	1.16	0.87	0.15	2%	1.43	1.62	0.17
Impacts of the Policy Shocks							
Removal of Price Instruments							
Risk Neutral	-1.87	-1.62	0.15	-	0.52	0.31	0.17
Risk Aversion	-2.03	-1.52	0.16	2.03%	0.56	0.34	0.17
Removal of Direct Payments							
Risk Neutral	-1.34	0.93	0.16	-	0.28	0.19	0.17
Risk Aversion	-1.46	1.02	0.16	2.04%	0.31	0.21	0.17

and after 50 years in the stochastic model with risk aversion, as it takes longer time for the expected volatility (σ) converge to the steady state with risk aversion. The first part of table 3 presents the new baseline values with respect to the calibration of risk preferences' parameters.

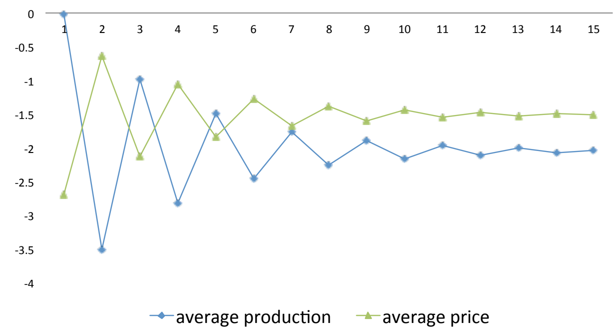
The productivity shocks outside Europe leads to a price volatility of 0.17 in the RoW and of 0.15 in the EU at the stochastic steady state. The level of world volatility is consistent with the measured volatility while the EU one is not(European Commission 2010). As will be shown below, this is due to policy representation where there is a perfect price transmission (modulo the Armington product differentiation assumption). Compared to the initial point used in the static and dynamic versions, the EU wheat production increases by 1.09% under risk neutrality and by 1.16% under risk aversion. The EU wheat price increases by 0.92% under risk neutrality and by 0.87% under risk aversion. Overall, the productivity shocks in other regions bring positive effects on the EU and RoW production. These positive effects are due to the nonlinearity in the model, in particular, the convexity of the demand function.

Having obtained the new baseline, we implement the policy shocks at the 31^{st} year for risk neutral case and at the 51^{st} year for risk aversion case. Table 3 presents the converged values, and Figure 2 and Figure 3 show the evolution of European production and price for both policy scenarios.

With the removal of price instruments, the economy converges to a new stochastic steady state in around 15 years. We observe similar evolution paths and modest differences between

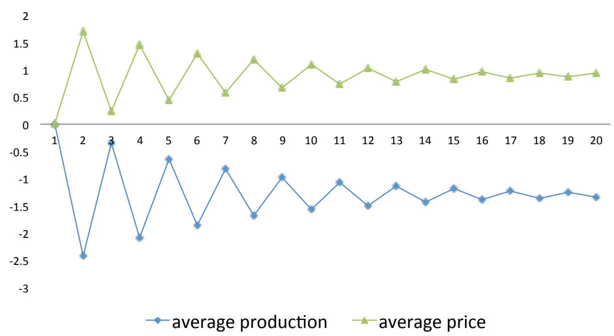


(a) Risk Neutral

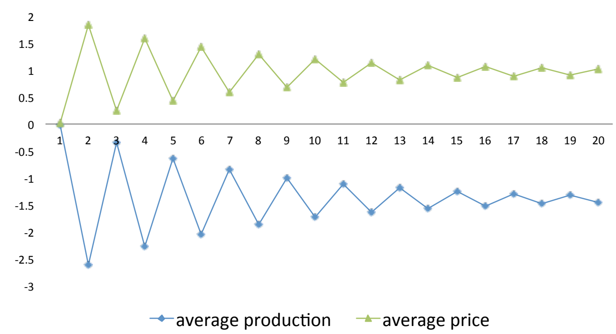


(b) Risk Aversion

Figure 2: Exogenous Policy: Evolution of the EU Wheat Production and Price following the Removal of Price Instruments (in percent compared to the baseline)



(a) Risk Neutral



(b) Risk Aversion

Figure 3: Exogenous Policy: Evolution of the EU Wheat Production and Price following the Removal of Direct Payments (in percent compared to the baseline)

the impacts of the two cases with or without risk aversion. The price volatility in Europe increases slightly to 0.16 with risk aversion, while it remains the same at 0.15 for the risk neutral case. As a result, the risk premium of the EU farmers increases by a small amount from 2% to 2.03%.

Although the price volatility does not change much from the baseline, we find that the risk-averse wheat producers in Europe reduce their production slightly more (by 2.03%) compared to risk-neutral producers (by 1.87%). As discussed before in Table 1, the risk-averse producers have higher price elasticities than risk-neutral farmers. The trade liberalization puts a downward pressure on the EU domestic price, the risk-averse farmers produce less than the risk neutral farmers. With regard to the impacts on price, we find that at the converged steady state, the EU wheat price decreases by 1.52% with risk aversion and by

1.62% without risk aversion.

With the removal of direct payments, the economy reaches the steady state after 20 years. Again, there is no obvious difference between the evolution paths with and without risk aversion (Figure 3a and Figure 3b). The results in Table 3 suggest first that the policy shock has a limited impact on the price volatility, which increases slightly from 0.15 to 0.16 for both risk attitude. The reason for this small impact is that the price volatility is mainly induced by the productivity shocks in other regions, on which the European policy reform has very limited influence. Second, we find as expected that the risk-averse producers in Europe reduce their wheat supply a little more (by 1.46%) compared to the risk neutral producers in Europe (by 1.34%). Accordingly, the wheat price in Europe increases more in the risk-aversion case (by 1.02%) than under risk neutrality (by 0.93%). The intuitions behind these results are the same as mentioned before with the static version.

In sum, under the exogenous policy representation, the market impacts of price instruments are larger than those induced by direct payments. The results obtained from the stochastic models do not deviate much from the static and dynamic results in Table 2. This indicates that adding the risk attitude and the stochastic productivity has not brought a significant impact. Although there are differences between the market impacts with or without risk aversion, the differences are quite modest. Our finding is consistent with previous findings, that is, the impacts of considering the economic agents' risk aversion are limited (Burfisher et al. 2000 Gohin and Treguer 2010). In this particular case, we conclude that risk aversion does not matter much for the assessment of market impacts of CAP reforms.

3.3.4 Results from the Stochastic Version with Endogenous Policy

Although the exogenous policy assumption is widely adopted, in real situations, especially for agricultural products in the EU, we are more likely to have an endogenous policy which prevents the domestic price from fluctuating too severely with the world price. Under this consideration, we now turn to the stochastic version with endogenous policy.

As usual, we first simulate the new baseline brought by the productivity shocks (Table 4). Different from the stochastic version with exogenous policy, the economy converges to the new steady state much faster (around 5 years) both with and without risk aversion. On the one hand, the price volatility in the EU is much lower, which is at the value of 0.09, compared to a volatility of 0.15 with exogenous policy, and it remains at 0.17 in the RoW for both policy representations. This is much more consistent with historical volatilities on both EU and world market prices (European Commission 2010). On the other hand, the average

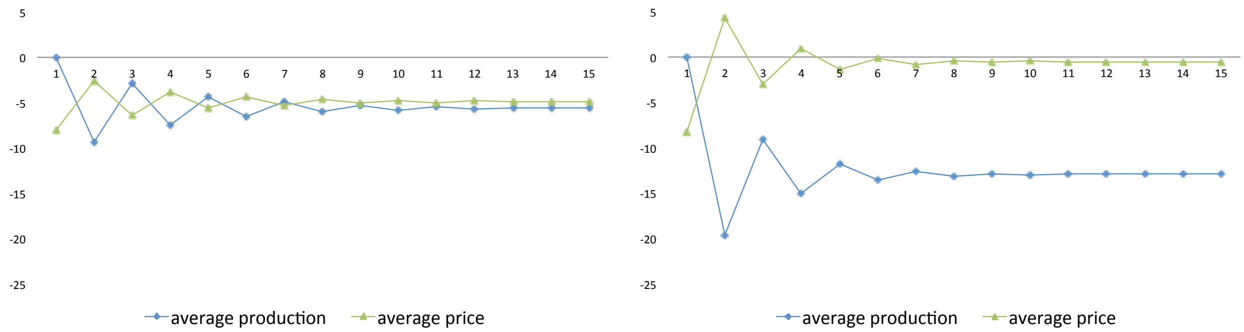
Table 4: Impacts of the Removal of CAP Instruments under Endogenous Policy Representation (production and price in percent with respect to the baseline)

	European Union				Rest of the World		
	Production	Price	Volatility(σ)	β	Production	Price	Volatility(σ)
New Baseline with Productivity Shocks							
Risk Neutral	5.07	4.39	0.09	-	-0.10	0.77	0.17
Risk Aversion	5.51	4.32	0.09	2%	-0.22	0.69	0.17
Impacts of the Policy Shocks							
Removal of Price Instruments							
Risk Neutral	-5.56	-4.91	0.15	-	2.07	1.17	0.17
Risk Aversion	-12.92	-0.52	0.16	7.14%	3.91	2.46	0.18
Removal of Direct Payments							
Risk Neutral	-1.84	0.30	0.09	-	0.52	0.34	0.17
Risk Aversion	-2.83	0.45	0.09	2.40%	0.80	0.52	0.17

EU wheat price raises as much as 4.39% under risk neutrality and 4.32% under risk aversion. Accordingly, the EU wheat production raises by 5.07% and by 5.51% respectively. The low price volatility and the high price increase are due to the endogenous policy representation: when the positive productivity shocks induce an expansion of wheat production outside Europe and a decline in wheat world price, the endogenous import tariffs and export subsidies in Europe increase to protect the EU price from dropping below a price floor. It erases the negative fluctuation below the price floor and leads to a price stabilization effect. As a result, the EU wheat price is less volatile and converges faster to a higher steady state price. With regard to the rest of the world, the EU price stabilization policy has limited effect on the world price volatility, since the EU market is not large enough to significantly influence the world price fluctuation (according to the GTAP database). Nevertheless, the increase of EU wheat production leads to a decrease in RoW wheat production and a different baseline for the RoW.

Next, we perform the policy shocks in 2021 (10 years after the initial year). The second part of Table 4 presents the converged results, Figure 4 and Figure 5 show the evolution of production and price in both policy scenarios.

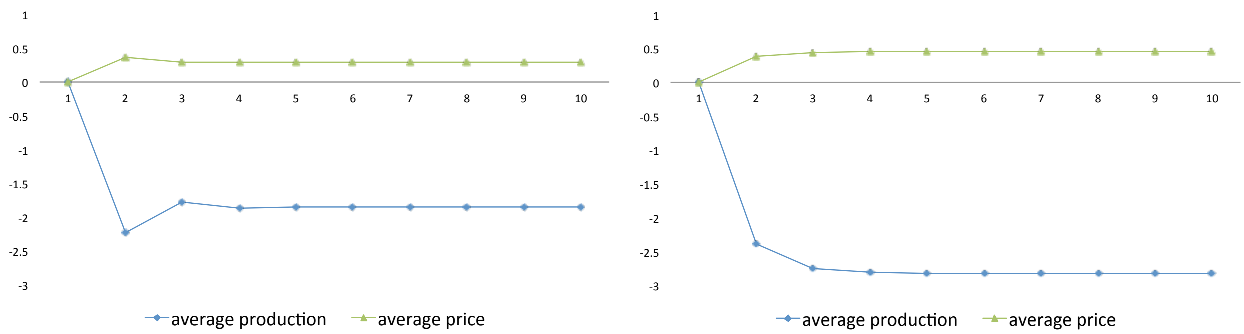
After the removal of price instruments, the economy moves to the stochastic steady state in 15 years in the risk neutrality case and in 10 years in the risk aversion case. The difference between the impacts with and without risk aversion is no longer negligible: the risk averse wheat producers in Europe reduce their production much more (by 12.92%) than the risk



(a) Risk Neutral

(b) Risk Aversion

Figure 4: Endogenous Policy: Evolution of the EU Wheat Production and Price following the Removal of Price Instruments (in percent compared to the baseline)



(a) Risk Neutral

(b) Risk Aversion

Figure 5: Endogenous Policy: Evolution of the EU Wheat Production and Price following the Removal of Direct Payments (in percent compared to the baseline)

neutral producers (by 5.56%), and the EU wheat price decreases much less (by 0.52%) in the risk averse case than that of the risk neutral case (by 4.91%). To explain this important difference, we know first that the removal of price instruments put a downward pressure on the EU wheat price. Since the risk-averse EU farmers have higher price elasticities than the risk-neutral ones, they reduce their production more when they expect the wheat price to decrease. We've discussed this mechanism in the exogenous policy part, this effect exists but not big enough if the farmers' risk premium stays around the baseline of 2%. Then additionally, removing price instruments eliminates the endogenous policy and its price stabilization effects. As a result, the price volatility in Europe rises to a considerable large level (0.16) compared to the baseline (0.09). Under the assumption of $CARA$, the risk premium parameter β depends on the price volatility, and it increases from 2% to 7.14%.

With this great increase in risk premium, the price elasticities of the risk averse producer rises to a much higher level than that at the baseline. To sum up, with the combined effects of the decrease in expected price and the increase in expected volatility, the risk averse EU farmers reduce their production much more sharply than the risk-neutral farmers.

We also find that risk aversion leads to different impacts after the removal of direct payments. Under the endogenous policy, it takes only around 5 years to converge to the steady state. Figures 5a and 5b show the evolution paths with and without risk aversion: the discrepancy lies especially between the second year and the third year after the policy shock. In the risk aversion case, the production continues to fall despite the increase in the output price expectation, while in the risk-neutral case, production rebounds a little with the increase in output price expectation. We also find in Table 4 that the final converged wheat production in Europe declines more (by 2.83%) in the risk aversion case compared to the risk neutrality case (by 1.84%), and the EU wheat price increases more (by 0.45%) with risk aversion than without risk aversion (by 0.30%). This is because under the endogenous policy representation, removing direct payments leads to an increase in price volatility in Europe from 0.086 to 0.094, so that the risk premium of the risk averse producers rises from 2% to 2.40%. As a result, the risk-averse producer becomes more sensitive to the increase in land price expectations, and they reduce their supply more following the removal of land subsidies.

In sum, under the endogenous policy representation, the results from the stochastic version are no longer similar to the static and dynamic results. This indicates the importance of adding the stochastic dimension in the modeling frameworks. Including risk aversion leads to much larger market impacts following the removal of CAP instruments: the risk-averse farmers reduce their production much more than the risk-neutral ones. In this case, risk aversion matters for farmers' decisions and it has a large influence on farm productions and market prices.

3.4 Sensitivity Analysis

3.4.1 Wealth Effect: Sensitivity to the Risk Aversion Parameter

One assumption of our previous simulations is that the producers exhibit constant absolute risk aversion (CARA). A large literature assesses the impact of farm payments on production through the so called wealth effects. They assume that farmers exhibit decreasing absolute risk aversion (DARA). To approximate this effect in our stochastic version where farmers'

Table 5: Wealth Effect: Impacts of the Removal CAP Instruments under Decreasing Absolute Risk Aversion (production and price in percent with respect to the baseline)

	European Union				**Rest of the World**		
	Production	Price	Volatility(σ)	β	Production	Price	Volatility(σ)
Stochastic version with exogenous policy							
Removal of Price Instruments	-3.69	-0.55	0.16	3.11%	0.94	0.61	0.17
Removal of Direct Payments	-2.99	-2.09	0.16	3.12%	0.67	0.47	0.17
Stochastic version with endogenous policy							
Removal of Price Instruments	-17.83	2.86	0.17	11.51%	5.15	3.34	0.18
Removal of Direct Payments	-6.43	1.46	0.10	4.30%	1.84	1.19	0.17

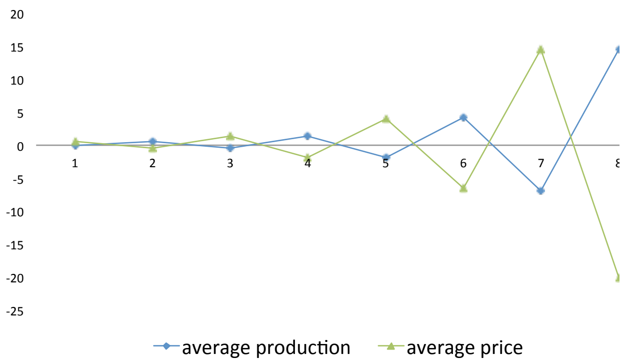
wealth has not been explicated, we increase the EU farmers' absolute risk aversion parameter ρ by 50% from the initial estimate, so that the risk premium represents 3% of the receipts. At the same time, we simulate the policy scenarios in the stochastic model. Table 5 reports the simulation results at the stochastic steady state for both the exogenous and the endogenous policy representations.

Although risk aversion does not matter under exogenous policy with CARA, including the wealth effect reveals a relatively larger production effect. The wheat production decreases by 3.69% following the removal of price instruments and decreases by 2.99% following the removal of direct payments. The level of decrease is about 1.60% higher than that under DARA due to the wealth effect.

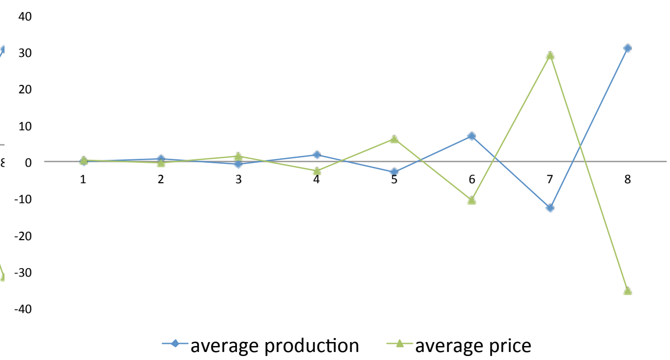
As risk aversion already matters under endogenous policy with CARA, it plays an even more important role if the wealth effect is considered. The sensitivity results show that EU farmers reduce their production by 17.83% with the removal of price instruments and by 6.43% with the removal of direct payments. This production cut effect is much more intense than that in the CARA case due to our approximation of the wealth effect.

3.4.2 The Case of Coarse-grains

In previous part, we focus our analysis on wheat, now we turn to coarse grains. We repeat all the simulations by replacing the assumptions on wheat to the assumptions on coarse grains, for example, we assume now that the EU coarse grains farmers are risk averse, while other

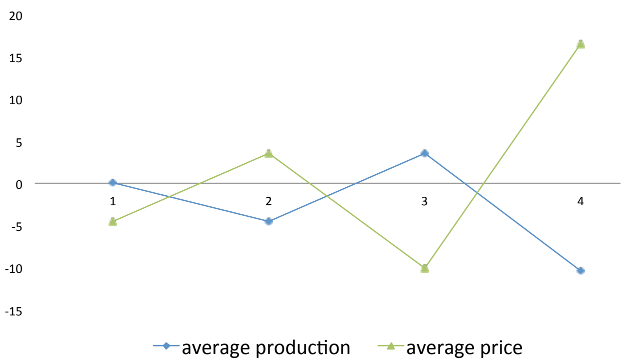


(a) Risk Neutral

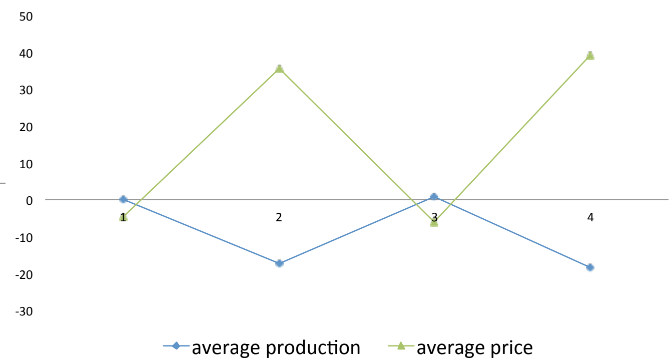


(b) Risk Aversion

Figure 6: Exogenous Policy : Evolution of the EU Coarse Grains Production and Price with Productivity Shocks (in percent compared to the initial baseline)



(a) Risk Neutral

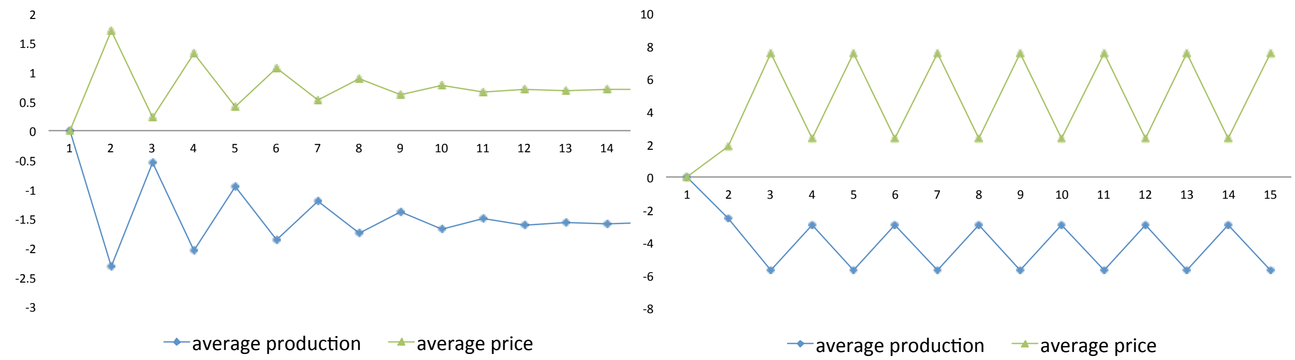


(b) Risk Aversion

Figure 7: Endogenous Policy : Evolution of the EU Coarse Grains Production and Price following the Removal of Price Instruments (in percent compared to the baseline)

parameters and policy scenarios remain the same.

Figures 6 and 8 present the simulation results. We start with the exogenous policy representation. We first need to obtain the new stochastic steady state after introducing the productivity shocks. However, figure 6 suggests that the evolution of production and price diverges and there is no stochastic steady state for this dynamic system with or without risk aversion. This divergence is not surprising because firstly, without the endogenous policy which stabilizes the price, the shocks cause more severe market fluctuations especially under naïve expectations. More importantly, compared to wheat, the Armington elasticity for coarse grains used in tht GTAP-Agr is lower, hence the price elasticity of total demand is lower (in absolute terms). Consequently, the dynamic system is more likely to diverge due



(a) Risk Neutral (b) Risk Aversion

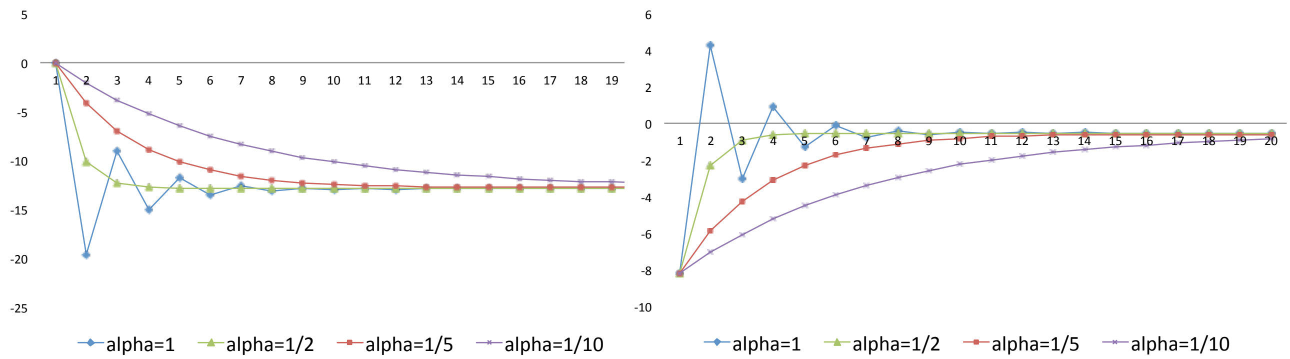
Figure 8: Endogenous Policy : Evolution of the EU Coarse Grains Production and Price following the Removal of Direct Payments (in percent compared to the baseline)

to a steeper demand curve of coarse grains.

Under the endogenous policy representation, the economy reaches the stochastic steady state with the productivity shocks after 10 years. On the one hand, with the removal of price instruments, the dynamics diverges quickly at the 4^{th} year with or without risk aversion (Figure 7). As explained above, this divergence is caused by the relatively lower Armington elasticity for coarse grains. On the other hand, with the removal of direct payments and in the case without risk aversion, the EU corn production and price converges to the new stochastic steady state after 15 years. The EU corn production decreases by 1.58% and the EU corn price increases by 0.69%. In the case of risk aversion, the dynamic could not reach the convergence, but loops around a certain production and price level (Figure 8b). This is because risk aversion increases the elasticity of supply on coarse grains, when it increases to a similar value as the elasticity of demand, the dynamic could not converge but ends of in loops.

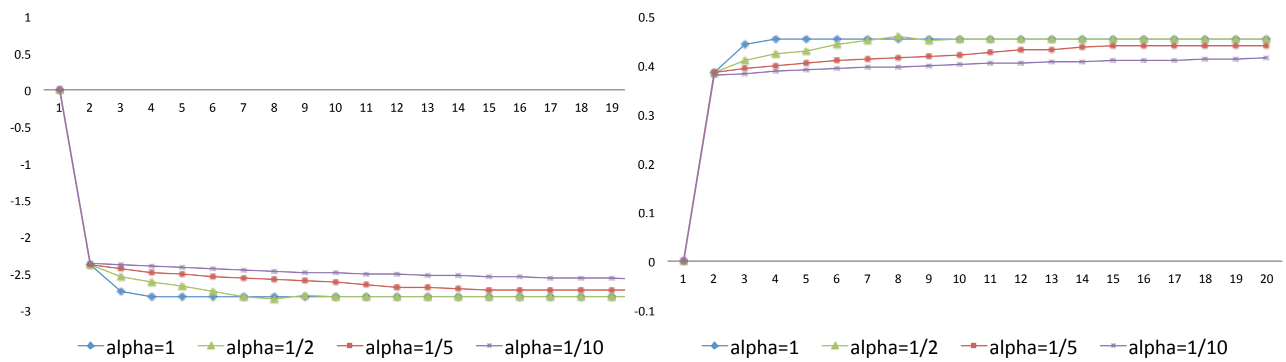
3.4.3 Sensitivity to the Historical Weighting Parameter

In our previous simulations, we assumed that the historical weighting parameter α equals 1. It indicates that the agents react immediately to the market price change. Femenia and Gohin (2011) demonstrate that α has a significant impact on market dynamics. More precisely, the system is more likely to diverge when α getting close to one. This is an important reason why we encountered divergence in the coarse grains case. In the case of wheat, the dynamics converges despite of naïve expectations because the Armington elasticity for wheat is relatively higher so that the total demand curve is relatively flatter. In



(a) Production (b) Price

Figure 9: Risk Aversion & Endogenous Policy : Evolution of the EU Wheat production and Price following the Suppression of Price Instruments (in percent compared to the baseline)



(a) Production (b) Price

Figure 10: Risk Aversion & Endogenous Policy : Evolution of the EU Wheat production and Price following the Suppression of Direct Payments (in percent compared to the baseline)

order to attain convergence for every situation and to verify the role of different expectation schemes, we decrease α from one (completely naïve) to 0.1 (nearly myopic) on both price and volatility expectations in our stochastic model with risk aversion.

Figures 9 and 10 show the evolution paths of production and price regarding different α after removing the CAP instruments under endogenous policy. We obtain similar results as Femenia and Gohin (2011). First, the dynamics is much smoother with the lower α. This is because when the agents react slowly to the price news, the fluctuations in the dynamics become less intense. It solves the divergence problem we encounter in the coarse grains case: if we use a historical weighting parameter of 1/5, we obtain converged corn production and price with productivity shocks and policy shocks. Second, although the smooth levels are different, the converged dynamic systems get to the same[1] stochastic steady state regarding different values of α. Except that the lower the α, the more periods are needed to reach the stochastic steady state. For example, in the stochastic model with risk aversion, endogenous policy and simulating the removal of price instruments, it takes 8 years to reach the steady state when α is 1, 15 years when α is 1/5, and more than 20 years when α is 1/10. This is reasonable because the slower the agents react to market price news, the slower the dynamics reaches the final equilibrium.

This sensitivity analysis implies thus that α influences the smooth level of the dynamics, the length of period needed to reach the stochastic steady states. As long as the system converges, it converges to the same stochastic steady state whatever values of α.

4 Conclusion

The Common Agricultural Policy (CAP) has been reformed several times with shifts from initial market price support to decoupled payments. Many models have been developed assess the market impacts of these reforms, but without explicitly introducing the stochastic dimension. In this paper, based on the standard static GTAP-Agr model and a dynamic version of GTAP-Agr model, we propose a stochastic PE/CGE modeling framework in which we introduce exogenous productivity shocks and farmers' attitude towards risks. We investigate to what extent the farmers' risk attitude matters in assessing the market impacts of CAP instruments.

We show that under the endogenous policy representation, compared to risk neutrality, risk aversion leads to larger market impacts at the stochastic steady state after the removal of CAP instruments. In particular, risk aversion does alter the farmers' production decisions in the way that risk-averse farmers have higher price elasticities of supply. With the introduction of risk aversion, price volatility becomes important to the producers' decisions through its influence on the risk premium. As the CAP reforms under the endogenous policy increase considerably the market fluctuations, the farmers' risk premium increases with the price volatility and leads to larger market impacts. Moreover, if the farmers exhibit decreasing absolute risk aversion, the additional wealth effects will bring even larger market impacts. Under the exogenous policy representation, our findings are similar to previous ones: including farmers' risk attitude brings limited difference in assessing market impacts of the CAP instruments. This is because with exogenous policy, the CAP reforms bring

[1] at the precision level of 10^{-3}

limited influences on price volatility, consequently, the risk premium which remains at the initial level is not large enough to make a difference. In sum, our findings imply that risk aversion matters in assessing the CAP instruments particularly when the policy initially prevent price drops.

As usual our modeling framework is subject to some limiting assumptions. For example, we assume that capital is fixed, so that the investment equals the capital depreciation for each period. In fact, risks and risk aversion exist not only in production decisions, but also in inter temporal saving and investment decisions. It is thus worthwhile to extend the recent model to a stochastic model with investment, while risk aversion is implemented in production, investment and saving decisions. We can also enlarge the current analysis with hedging issues on contingent markets or by considering a portfolio of products by farmers instead of focusing on only one product.

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