Since the financial and food price crises of 2007, market instability has been a topic of major concern to agricultural economists and policy professionals. This volume provides an overview of the key issues surrounding food prices volatility, focusing primarily on drivers, long-term implications of volatility and its impacts on food chains and consumers.

The book explores which factors and drivers are volatility-increasing and which others are price level-increasing, and whether these two distinctive effects can be identified and measured. It considers the extent to which increasing instability affects agents in the value chain, as well as the actual impacts on the most vulnerable households in the EU and in selected developing countries. It also analyses which policies are more effective to avert and mitigate the effects of instability.

Developed from the work of the European-based ULYSSES project, the book synthesises the most recent literature on the topic and presents the views of practitioners, businesses, NGOs and farmers’ organisations. It draws policy responses and recommendations for policy makers at both European and international levels.

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Agricultural Markets Instability
Revisiting the recent food crises
Edited by Alberto Garrido, Bernhard Brümmer, Robert M’Barek, Miranda P.M. Meuwissen and Cristian Morales-Opazo

Chapter 4
Medium-term drivers of food markets’ variability and uncertainty

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4 Medium-term drivers of food markets’ variability and uncertainty

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1 Introduction

The evolution of agri-food prices in the last decade has led to increasing concerns about the development of agricultural markets, with many forward-looking studies expecting future price levels above the historical trends and higher price variability (von Lampe et al., 2014; OECD-FAO, 2013). From global food security and farm income perspectives, it is crucial to understand how different drivers of change and their underlying uncertainties could shape future agri-food markets.

Different factors affecting the development of agricultural commodity prices work together and could lead to large price fluctuations, as observed during the food crisis in 2006–2008. Amongst those drivers, the literature mentions harvest failures, exports restrictions, biofuels policies, climate change, declining stocks, speculation, low economic growth, currencies exchange rates, population growth, and diet changes, among others (see Chapter 3 and Brümmer et al., 2013; Headey and Fan, 2008; Trostle, 2008; Baffes and Haniotis, 2010; Naylor and Falcon, 2010; FAO, 2009; FAO et al., 2011; Gilbert, 2010). Broadly speaking, these drivers can be classified into two major groups: socioeconomic (e.g., macroeconomic and socio-demographic indicators, including policies) and biophysical (e.g., climate change, land use, pressure on natural resources, etc.). Previous studies, such as those quoted above, have addressed the impact of several drivers mostly based on econometric approaches. However, the analysis of the potential development of agri-food systems cannot depend on the observed past only, but has to take into account also different assumptions on policies and the economic agents’ view of the future. A plausible way to incorporate also future expectations on specific factors is by employing agro-economic models.

Agro-economic models cover a relatively large number of variables affecting agri-food markets while capturing the complexity of the relations between them. In addition, these models include a forward-looking perspective on agricultural markets called “baseline”. The baseline comprises a set of assumptions based on the consensus of different market experts, which feeds the economic
models, such that the result is a coherent projection of the market’s development for the forthcoming years. The main purpose of agroeconomic models, in addition to the projection (baseline), is the usage for scenario analysis. The interest is to observe the changes with respect to a reference scenario or “baseline” when the assumptions are different. The scenarios can include a modification of one or different variables feeding the model and can be deterministic or stochastic.

With a view to contribute to the current debate about the likely development of price level and variability on agri-food markets in the medium-term (10 to 15 years), we examine in this chapter the main drivers and their associated uncertainties. For this purpose, we implement two approaches:

- The analysis of socioeconomic and policy drivers, together with yield fluctuations, by means of a partial stochastic approach: In a baseline scenario for 2023, we consider the main sources of uncertainty affecting the agri-food markets. We use the 2013 version of the AGLINK-COSIMO model as employed for the European Commission’s baseline.
- The analysis of climate change drivers by means of a bioeconomic assessment: We explore the consequences of climate change scenarios on agricultural markets at a highly disaggregated spatial scale combining the biophysical modelling platform BioMA and the agroeconomic model CAPRI.

Both analyses are complementary. On the one hand, the partial stochastic analysis considers the main sources of systematic uncertainty around the macroeconomic market drivers, oil price, and yield. On the other hand, the scenario analysis with CAPRI-BioMA explores how the EU and world agri-food markets could be affected by climate change toward the year 2030, when climate experts expect tangible impacts. Several scenarios of crop yield developments under climate change are included in the analysis, taking into account also the degree of carbon fertilization. The use of both types of analyses allows us to have a broader understanding of potential drivers of price variability in the future.

2 Impact of macroeconomic and yield uncertainty on global prices

Among the socioeconomic drivers affecting price volatility, macroeconomic indicators and the oil price are often identified as having an important impact (Artavia et al., 2014; Brümmer et al., 2013; Abbott and Borot de Battisti, 2011; Baffes and Haniotis, 2010; Magrini and Donmez, 2013; Swinnen and Squicciarini, 2012; Tangermann, 2011). The vast literature has a strong focus on time series analysis using different types of autoregressive models. However, the interactions among drivers, market fundamentals, and policy are only partly
addressed. Research work by Gohin and Chantret (2010) using a computable general equilibrium (CGE) seeks to account for the macroeconomic linkages together with oil price shocks.

Aiming at complementing previous research, we address in a comprehensive way different sources of macroeconomic, oil price, and yield uncertainties, which might have an impact on the development of agri-food markets. For this purpose, we employ the stochastic version of AGLINK-COSIMO, a multi-region, recursive-dynamic partial equilibrium model. This approach has been implemented in previous publications, mainly the yearly agricultural outlooks published by DG Agriculture and Rural Development and OECD-FAO (EC, 2012, 2013, 2014; OECD-FAO, 2013, 2014). The methodology for estimating the uncertainty is described in Burrell and Nii-Naate (2013). For this exercise, we include 40 country-specific macroeconomic variables and 79 country- and commodity-specific yields as sources of uncertainty. Following the previous analyses with this tool, we use the coefficient of variation in the last year of the ten years projection period (CV2023) for the presentation of the model output.

The partial stochastic analysis allows for analyzing the variation of world market prices. The results for the main agricultural commodities are shown in Figure 4.1.

Among the crops, oilseeds have the highest level of variation, followed by its subproducts protein meal and vegetable oils. This is partially explained by the use of these crops in the feed industry. Oilseeds cannot be substituted that easily as they provide different levels of protein and oil (energy); supply shocks in high-protein content oilseeds (e.g., soybean) can only be offset by the use of other high-protein inputs, such as fish meal or milk powder, which are

![Figure 4.1 Coefficient of variation of world market prices in 2023.](image-url)
more expensive than soybean meal. In contrast, coarse grains and wheat are homogeneous in the sense that they are substitutes for the provision of energy. As grains can be easily substituted among them, supply shocks are offset, and the impact on variation is diluted. Along with this, there is a rapid economic growth surrounded by high levels of uncertainty in Brazil, Russia, India, and China (BRIC), increasing in particular the demand for meat and dairy, which affects the demand for oilseeds and grains.

High levels of uncertainty coming from large meat importers (BRIC) are transmitted into the different meat markets. Pork meat is exposed to uncertainty, which can be attributed to the increasing demand coming mainly from China. Dairy products, with most of the growth in demand for milk expected to come from India, exhibit similar levels of variation and are in general less variable than meats and crops. Finally, biofuels and sugar prices follow the oilseeds and subproducts (oils and meals) in terms of variation, strongly related to the biofuel policies.

The outcome of the overall uncertainty analysis provides a broad picture of the variation for the main commodities. Nonetheless, it does not allow discerning the main potential sources of uncertainty for each commodity. In order to analyze the impact of yield and macroeconomic uncertainty in isolation, the AGLINK-COSIMO model is run for each category of uncertainty separately. Figure 4.2 shows the results for macroeconomic and yield-related uncertainty alone, as well as the overall uncertainty outcome.

Macroeconomic uncertainty in general drives most of the price variation in the world market prices. This is because world prices are determined by trade, for which exchange rates and transport costs play a major role. The commodities

![Figure 4.2 Coefficient of variation of world market prices by partial stochastic scenarios in 2023.](image-url)
most affected by the macroeconomic uncertainty are biofuels and pork meat. In the case of biofuels, the linkage is through the oil price, which drives the demand for fossil fuel; notably binding mandates serve as a vehicle to pass the oil price uncertainty to biofuels. Concerning pork meat, economic growth in China and Russia is assumed to put more pressure on imports and the world demand. Yield uncertainty affects oilseeds the most; this is in part due to the past high levels of variation in Argentina, one of the main exporters of oilseeds and protein meals. In addition, other important exporters such as Ukraine and Kazakhstan (with large fluctuations in their oilseed yields) are expected to have an increasing share on the world markets, adding more uncertainties and variation to world prices. It should be noted that yield and macroeconomic uncertainty are not additive. The reason is that these two sources of uncertainty are assumed to be independent, and their effects can offset each other.

Separating the analysis by source of uncertainty permits identifying the main drivers of price variation. Next, we want to determine which macroeconomic indicator drives variation the most. For this purpose, we run different sources of macroeconomic uncertainty separately, although this approach deserves some words of caution. Macroeconomic variables are interrelated and this is omitted when they are used one-by-one in the model. Thus, our exercise is a sensitivity analysis that can help to identify the impact of specific sources of uncertainty while keeping the remaining ones constant. The results are shown in Figure 4.3.

![Figure 4.3](image-url) Coefficient of variation of world market prices by macroeconomic partial stochastic scenarios in 2023.
The first outcome is the reduction of the variation when looking at the macroeconomic indicators separately, in part reflecting that macroeconomic indicators do not tend to offset their effects. The groups with the largest impact on the price variation are crude oil price and exchange rate. Crude oil price is particularly relevant for biofuels, as biofuels and fossil fuel consumptions are linked. Oil price affects all the commodities by means of the cost of production, more specifically energy, fertilizer, and transport costs. The exchange rate plays a more important role in ethanol than in biodiesel, because there is substantial trade of ethanol in world markets, mainly involving Brazil and the United States. The main driver is the uncertainty of the exchange of the Brazilian Real against the USD. Other commodities largely affected by the exchange rates are oilseeds, coarse grains, and pork meat. Oilseeds and coarse grains are mainly produced in South America (in particular, Argentina and Brazil), for which large fluctuations of exchange rates are recorded; moreover, the main importers for meat and oilseeds are rapid-growing economies, such as Russia and China. The fluctuations in the exchange rate lead to different levels of competitiveness in the world markets, which impact the global trade and the world prices. The third most affecting item is the GDP, which is linked to the production and economic growth. Finally, the consumer price index and GDP deflator uncertainty are more likely to affect through the demand, by affecting the prices for consumers and the purchasing parity power. In general, it can be concluded that price variation will depend on how large the exogenous uncertainty is, the number of linkages that it has along the agri-food chain, and in the global markets how important is the country where the uncertainty comes from.

Together with the analysis of price volatility drivers, it is of interest to analyze if the price variation will differ depending on the price level. In order to do so, we run a scenario with imposed export taxes in Russia, Ukraine, and Kazakhstan (RUK region) for wheat. This restriction causes a decrease on the global supply, thus putting pressure on prices. The baseline projection for the world wheat price in 2023 is 270 USD/ton. Imposing the restrictions on exports in the RUK region causes the price to increase to 338 USD/ton in the same year, which represents an increase of 25% with respect to the baseline. The range for the 10th–90th percentiles goes from 215 to 326 USD/ton in the reference scenario (baseline). With the restrictions, the range values go from 274 to 405 USD/ton, which is broader than the reference scenario. Nevertheless, the increase in the price level does not translate into a higher coefficient of variation, which remains close to levels of 10% (Figure 4.4).

The results presented above are based on certain assumptions. First, the uncertainty accounted for is exogenous; it is neither increased nor decreased by higher taxes on exports. Second, the supply, demand, stocks, and own-price elasticities remain constant for the different shocks, and they are not triggered by the price level. Finally, the uncertainties are affecting the price volatility through different channels, which are not affected by assuming higher export
3 Influence of climate change on midterm agri-food market developments

3.1 Introduction

In this section, we turn our attention to the environmental drivers. Climate change is acknowledged for being one of the most determining environmental drivers for the future development of agricultural markets. There is a growing body of literature on the biophysical and economic effects of climate change on agriculture (Parry et al., 2004; Nelson et al., 2009; IPCC, 2014). In a recent review of the main contributions, Fernández and Blanco (2014) highlight that results from different studies are not easily comparable and often contradictory, showing that there is a wide range of uncertainty linked to climate projections, crop productivity effects, and market adjustments.

Above all, future crop yield developments are subject to considerable uncertainty, particularly with regard to climate projections and the degree of carbon fertilization effect (Rosenzweig et al., 2013). To assess the influence of these uncertainties in the development of agricultural markets over the next 20 years (from 2010 to 2030), we defined a set of simulation scenarios, all based on the same Shared Socioeconomic Pathway, SSP2 (Kriegler et al., 2012), and the highest Representative Concentration Pathway, RCP 8.5 (van Vuuren et al., 2011). The scenarios differ in (1) the influence of CO₂ effects, based on the

Figure 4.4 Price level (left graph) and variation (right graph) for wheat price in 2023.
extreme cases with and without carbon fertilization, and (2) the climate projection, based on two different global circulation models (GCMs), HadGEM2\textsuperscript{1} and IPSL-CM5A-LR.\textsuperscript{2} The former represents a warmer and dryer climate while the latter implies relatively milder temperature and higher precipitation. The resulting simulation scenarios\textsuperscript{3} were chosen in order to disclose as much information as possible from the uncertainties related to climate change effects on crop production and prices.

### 3.2 Bioeconomic approach

The bioeconomic modelling approach used in this study consists of combining global biophysical and agroeconomic models. Biophysical models project crop yield effects of climate change under various climate scenarios (defined by GCMs) and those yield effects are incorporated into the agroeconomic model CAPRI in order to evaluate impacts on production and prices. CAPRI represents a unique combination of regional supply-side models with a global market model for agricultural products that provides simulated results for the EU at subnational level, whilst, at the same time, simulating global agricultural markets (Britz and Witzke, 2014). This modelling approach allowed for assessing the biophysical and economic effects of climate change on agriculture both at the global and regionalized levels within the EU.

At the European level, we used the WOFOST (World Food Studies) crop model (Van Diepen et al., 1989) to simulate the biophysical effects of climate change and the carbon fertilization on crop yields throughout the European Union. Biophysical simulations performed at a 25km grid resolution provided changes in crop yields for nine of the most widely grown crops in the EU. The results of the simulations were aggregated at regional, national, and EU28 levels, using regional statistics on crop areas.

For non-EU regions, climate-induced changes on crop yields were taken from available projections from the ISI-MIP modelling initiative, in particular from simulations with the LPJmL model (Bondeau et al., 2007).

### 3.3 Dealing with climate change uncertainties

**Biophysical effects of climate change**

Overall, as Figure 4.5 illustrates, crop yields tend to rise over the baseline when the CO\textsubscript{2} effect is taken into account and to fall with no carbon fertilization. On average, maize presents the lowest range of variation, with a decrease down to $-1.4\%$ and an increase up to $2\%$, while soybean displays the highest variability (between $-5.2\%$ and $12\%$).

Taking a closer look at the EU, we observe similar patterns (except for maize and potatoes, which seem to be more affected by climate change regardless of the carbon fertilization effect), with decreasing yields in all scenarios. Average results hide, however, significant regional disparities both at the global and EU levels.
In this section, we discuss the climate-induced effects on agri-food markets by comparing – for the time horizon 2030 – the four simulation scenarios to the baseline or reference scenario.

In scenarios accounting for CO\textsubscript{2} effects, the exogenous increase in crop yields globally will be counterbalanced by a decrease in crop prices. In absence of carbon fertilization, the exogenous decrease in crop yields will drive up crop prices. Price effects will lead to interregional adjustments in production, consumption, and trade. Thus, the result of the diverging effects on crop yields and prices will determine the level of production and price for each region or country.

Figure 4.5 Percentage change on simulated actual yields between 2010 (present climate) and 2030 (world and EU averages).

Socioeconomic impacts

In this section, we discuss the climate-induced effects on agri-food markets by comparing – for the time horizon 2030 – the four simulation scenarios to the baseline or reference scenario.
As shown in Figure 4.6, global crop price increases in scenarios without CO\textsubscript{2} effects fall in the range –3.5% to –8.0%, depending on the crop and the climate projection. Price increases partially offset the negative productivity effects. In general, the patterns of global production follow the simulated yields changes, with the exception of soybean in the HadGEM2 scenario, where production increases.

Focusing on scenarios with CO\textsubscript{2} effects, we find opposite results. Global crop prices decreases in the range of –3.7% to –18.2% result in global production increases in the range 0.5% to 2.2%. The degree of carbon fertilization...
Drivers of variability and uncertainty

is, therefore, a major driver of climate effects and determines the direction of changes. While the influence of CO$_2$ fertilization is generally acknowledged, and the scenarios without CO$_2$ are rather unlikely, there is considerable uncertainty on the degree of the CO$_2$ effect.

Contrary to what we would have expected from the observed biophysical effects, a high variation in productivity, like in soybean, is not a sufficient condition for high variation in production, since it can be buffered by market effects (e.g., price variation). The considerable price responses to modest production variations reflect the relatively low demand elasticity for most of the agri-food products. Therefore, it is important to highlight that, besides yield changes, other factors – such as food demand – seem to have a strong influence on food production.

Focusing on the European Union, average EU yield effects – with carbon fertilization – are less positive than global yield effects and, because of market-driven adjustments, effects on EU production are more negative (Figure 4.7).

Due to differences in productivity shocks and market-driven adjustments, the comparative advantage of European agriculture will deteriorate in all scenarios. Impacts are unevenly distributed, however, across EU regions and crops. Figure 4.8 illustrates the regional heterogeneity of climate impacts on wheat production, the most cultivated crop in EU, for the HadGEM2 scenario.

Diverging regional impacts of climate change in agricultural productivity lead to adjustments in production, consumption, and trade flows. Particularly
for internationally traded products, this will lead to changes in regional self-sufficiency rates. In this sense, international trade could represent an important mechanism to buffer the effects of climate change.

As highlighted in Figure 4.9, wheat self-sufficiency will decrease in all simulation scenarios in those regions more negatively affected by climate change (i.e., Europe, Australia, and New Zealand), while it will increase in those regions less negatively affected (America).
4 Conclusions and outlook

The functioning of agricultural markets is driven by biophysical and socioeconomic factors, as well as different policies. As these drivers are linked to different sources and levels of uncertainty, understanding how such uncertainties can influence future agricultural markets is crucial in facing food security challenges. Agroeconomic models identify crude oil prices and macroeconomic indicators, especially exchange rates, as main sources of price variability. Other drivers also have an influence, namely the GDP and consumer price index, the stocks levels, as well as weather shocks and climate change.

While market drivers have an impact on the price levels and the variation, the impact differs among markets and products. The commodities with high price variation linked to macroeconomic indicators are oilseeds (and its derivatives), because of their strong connections to biofuels and the meat/dairy markets; biofuels, whose variation is linked mainly to fossil fuels uncertainty; and meat, particularly pork, which is affected by exchange rates and increasing demand in emerging markets. In the world markets, the exogenous sources of uncertainty have similar impacts on price variation regardless of the price level.

Concerning the impacts of climate change on agriculture, both biophysical and economic results vary widely across scenarios, regions, and sectors. The carbon fertilization effect strongly influences the direction of effects for both EU and non-EU regions, leading to crop price increases in the absence of carbon fertilization and to price decreases when CO₂ effects are accounted for. Economic simulations show that crop prices will react to yield changes, attenuating the effects of climate change at the global level, but originating significant distribution effects across regions and sectors. Results suggest that agri-food market projections to 2030 are very sensitive to changes in crop productivity and, therefore, to the uncertainties linked to climate change.

Notes
1 The Hadley Centre Global Environmental Model version 2 (HadGEM2) developed by UK Meteorological Office Hadley Centre.
2 Institut Pierre-Simon Laplace Coupled Model version 5 (IPSL-CM5A-LR) developed by Institute Pierre-Simon Laplace in France (Dufresne et al., 2012).
3 Four simulation scenarios in total: HadGEM2-CO₂, HadGEM2-noCO₂, IPSL-CO₂, and IPSL-noCO₂.
4 Self-sufficiency in production is an indicator of import dependency, defined as the ratio of production to domestic consumption.

References


