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# Increasing volatility of input costs in the EU agriculture

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# Increasing volatility of input costs in the EU agriculture

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*Abstract*

*In this paper the impact of possible input cost developments on the EU agriculture is analysed under ceteris paribus conditions. Two scenarios are developed with the partial equilibrium model CAPRI. The scenarios assume symmetric input price changes in positive and negative directions around a projected baseline in year 2020. The magnitude of the input price changes are based on observed volatility. To measure the volatility, the annual time-series of the CoCo database were analysed, which contains input cost estimates for a multitude of agricultural activities and cost categories at the geographical level of the EU countries.*

*Our results suggest that the uncertainty in input cost development has a strong potential to affect commodity market balances and farm incomes. There is an ongoing discussion about possible policy measures to mitigate the negative impacts of price volatility on farm incomes. This study contributes to this discussion by estimating a share of 17 billion euros of EU agricultural income being put on risk every year. The analysis also identifies vulnerable regions and production technologies that are particularly affected by input price instability. It remains for further research to perform a systematic sensitivity analysis in order to explore the impact of input cost volatility fully on the model outcomes.*

*Keywords: input costs, volatility, CAPRI, farm income*

*JEL classification: Q13.*

## 1. INTRODUCTION

In recent years the pressure on European agriculture has grown, particularly on the cost side of production. Input cost development has seen an upward trend in the last decade, squeezing farm profit margins considerably. At the same time input prices have become more volatile, increasing the instability of farmers' income.

The drivers of the uncertainty in input cost development come partially from outside the agribusiness: energy prices, exchange rates and financial events. Other drivers are clearly generated by the agricultural commodity markets, e.g. the rise in feed costs which is partly due to the high cereal and oilseed prices of recent years. The sources of the increase and yearly fluctuation of total costs are sector specific. In the crop sector, the cost increase was mainly due to higher fertilizer, energy and seed costs in the past few years. Production costs in the livestock sector, however, closely followed the upward and downward movements in feed prices (European Commission, 2011).

This paper attempts to estimate the possible impacts of alternative production cost developments in the European agriculture. Special attention is drawn to the identification of the most affected regions and the most vulnerable production systems. The partial equilibrium model Common Agricultural Policy Regionalised Impact Modelling System (CAPRI[1]) is applied for the analysis. We focus our attention on the operating costs, i.e. on the cash expenditures that are necessary to operate.

An econometric estimation of the observed volatility of input prices is performed. Based on the estimation, scenarios assuming symmetrically higher and lower input prices are implemented in the CAPRI model. The results mark possible deviations from our projected baseline[2] in 2020 under the two different price development assumptions.

The model results suggest that, despite the increase in domestic commodity prices, higher production costs lead to a decline in agricultural income. Regions that are dominated by input intensive production systems or where farm profit margins are relatively low seem to suffer the biggest drop in income. The assumption of lower production costs drives the economic equilibrium to the opposite direction.

The calculated impacts clearly demonstrate that the volatility of input prices has the potential to significantly contribute to the increase in instability of farm incomes. An estimated 17 billion Euros of agricultural income is put on risk by input price volatility; a significant amount compared to e.g. the ca. 40 billion Euros available for direct payments under the Common Agricultural Policy. Therefore appropriate policy measures should be designed and made available to farmers to cope with the increased risks they face in the upcoming period

## 2. ESTIMATING THE VOLATILITY OF INPUT COSTS

This section addresses the observed instability of input prices. First an overview is provided on available data sources covering production costs in the EU countries. Then our measure of volatility is defined and, based on this definition, estimates are provided for those inputs and countries that are considered later in the scenario analysis.

### *2.1. Available data sources and their cost allocation models*

Data bases covering input costs in all EU Member States under a consistent cost allocation model are relatively scarce. The Farm Accountancy Data Network (FADN) maintains a database with EU-wide geographical coverage and standardized questionnaires targeting farm accounts, which is a valuable source of information. Production costs, however, are not broken down to the level of agricultural activities. To estimate production costs at activity level, adequate cost allocation models need to be developed.

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[1] http://www.capri-model.org/

[2] The baseline is the projected equilibrium state of the economy in the simulation year, assuming normal developments in the economy and status quo for the agricultural and trade policies. The CAPRI model is calibrated to this baseline and used for comparative analysis by developing alternative scenarios against the baseline.

The FACEPA 7th Framework Project[3] aimed to develop a general cost allocation model (‘General cost of production model’) using FADN farm records. The resulting model (based on seemingly unrelated regression analysis) and its implementation in a statistical programming language have been already made available for the wider research community (Offermann and Kleinhanss, 2011). It remains for further research to investigate the applicability of this approach in larger scale sectoral models, and particularly in the case of CAPRI.

The CoCo (Complete and Consistent) database is part of the CAPRI modelling framework and contains input price estimates for mineral fertilizers, fuel and energy costs, maintenance, pesticides, seeds, services and veterinary costs for all countries of the EU. The applied cost allocation model follows a Bayesian approach to distribute aggregate input demand to different production activities. Three sets of prior information are combined in a Highest Posterior Density Estimation (HPD) framework (Heckelei, Mittelhammer and Jansson, 2008):

- input coefficients estimated from FADN single farm records
- unit value statistics of the Economic Accounts for Agriculture (EAA)
- standard gross margins for agricultural activities from EUROSTAT

The CAPRI cost allocation model, therefore, builds on FADN cost estimates but combines it with other information sources for the following reasons:

- to achieve compatibility with EAA figures at activity/product level
- to address the differences in cost definitions between FADN and CAPRI
- to avoid estimations that are violates simple consistency constraints or economic considerations

The HPD-estimation framework is formulated as an optimization problem with a set of consistency constraints that link the priors. For example gross margin for an activity is defined as the difference between the revenue and the sum over all inputs used for that activity. Thus the gross margins coming from the third set of priors are combined with the revenues calculated based on the second set of priors and with the input coefficients of the first set of priors.

After having estimated the production costs in the base year, CAPRI builds up a projection until the simulation year (2020) assuming input saving technological progress and taking into account a general inflation rate.

The FADN Unit of DG Agriculture and Rural Development regularly publish reports analysing the FADN data records at sector level (European Commission, 2009, 2010a, 2010b, 2010c). The cost allocation models used for the FADN publications and for deriving the cost estimates of the CoCo database are different in many respects, resulting in differences in the final production cost figures.

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[3] The website of the project 'Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture' (FACEPA) is available under: http://www2.ekon.slu.se/facepa/

Compared to the CAPRI approach, the cost allocation models of the FADN reports concentrate more on specialised farms. The sample used for the beef farms report, for example, contains only farms specialized in cattle breeding or fattening according to a modified version of the "Typology of Grazing Livestock Systems" (Chatellier et al. 2000)

Another significant difference between the two cost allocation models above is how feed costs for livestock activities are calculated. The approach taken in the FADN report links it to crop activities by deriving it from seed, fertiliser and crop protection costs. CAPRI, on the other hand, includes a cross-entropy estimator for fodder prices. The estimator builds on the unit value statistics of own produced fodder and on the commodity balances (including feed use) derived from EAA. The estimation process tries to find fodder prices that reflect both the nutrient content and the production costs at regional level.

Some properties of the FADN reports make them unsuitable for our modelling approach. They do not provide long enough time-series for the econometric estimations (especially for the New Member States), and the product coverage is insufficiently small compared to that of CAPRI. Therefore the authors of this study opted to base their volatility estimates exclusively on CoCo data.

### *2.2. Volatility estimates*

The coefficient of variance (CoV) is used as the measure of volatility and is defined as the ratio of the standard deviation to the mean. The time series are first de-trended with a linear or log-log model in order to separate the trend from the unexplained rest. The model choice depends both on a goodness of fit test and the statistical significance of the trend parameter[4]. Our analysis is based on the unit values of the different input categories (for a full list of input categories see Table 1). The unit value definition is consistent with the EUROSTAT definition of unit value at producer prices[5].

Our calculation suggests that the main drivers of input costs volatility are fertilizer, fuel and energy prices. The CoV estimates (averaged over the EU-27 countries) are the highest for these items, the actual values being between 0.2 and 0.4 (see Figure 1, fertilizer is broken down to NPK-content). Please note that feed costs and animal purchases are not included here from a methodological reason explained later in the text.

[4] The code of the econometric estimation as well as the underlying data are publicly available at: http://github.com/trialsolution/input_costs

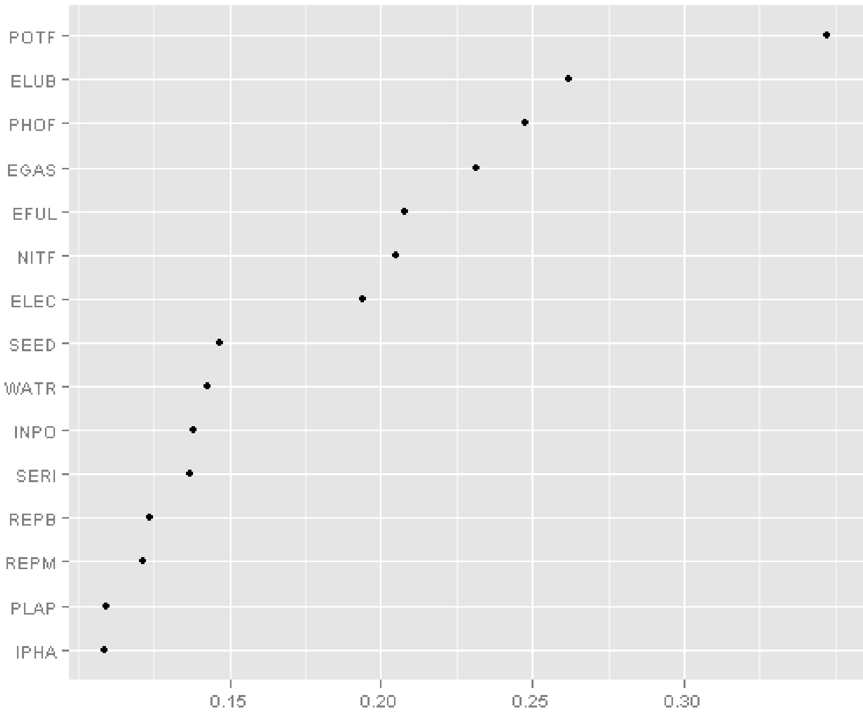
[5] According to the EUROSTAT definition, producer price is the amount receivable by the producer from the purchaser for a unit of a product minus value added tax (VAT), or similar deductible tax, invoiced to the purchaser.

Table 1: Inputs of the production activities in CAPRI

| Model code | Input category | Model code | Input category |
|---|---|---|---|
| *General inputs* | | *Other animal specific inputs* | |
| REPM | Maintenance materials | IPHA | Pharmaceutical inputs |
| REPB | Maintenance buildings | | |
| ELEC | Electricity | *Tradable feedstock* | |
| EGAS | Heating gas and oil | FCER | Feed cereals |
| EFUL | Fuels | FPRO | Feed rich protein |
| ELUB | Lubricants | FENE | Feed rich energy |
| WATR | Water balance or deficit | FMIL | Feed from milk product |
| INPO | Other inputs | FOTH | Feed other |
| SERI | Services input | | |
| | | *Non-tradable feedstock* | |
| *Other crop specific inputs* | | FGRA | Gras |
| SEED | Seed | FMAI | Fodder maize |
| PLAP | Plant protection | FOFA | Fodder other on arable land |
| CAOF | Calcium in fertiliser | FROO | Fodder root crops |
| | | FCOM | Milk for feeding |
| *Young animal purchases* | | FSGM | Sheep and Goat Milk for feeding |
| ICAM | Male calves | FSTR | Straw |
| ICAF | Female calves | | |
| IHEI | Young heifers | *Fertilizers* | |
| ICOW | Young cows | NITF | Nitrogen in fertiliser |
| IPIG | Piglets | PHOF | Phosphate in fertiliser [P2O5] |
| IBUL | Young bulls | POTF | Potassium in fertiliser [K2O] |
| ILAM | Lambs | | |
| ICHI | Chicken | | |

Source: own elaboration

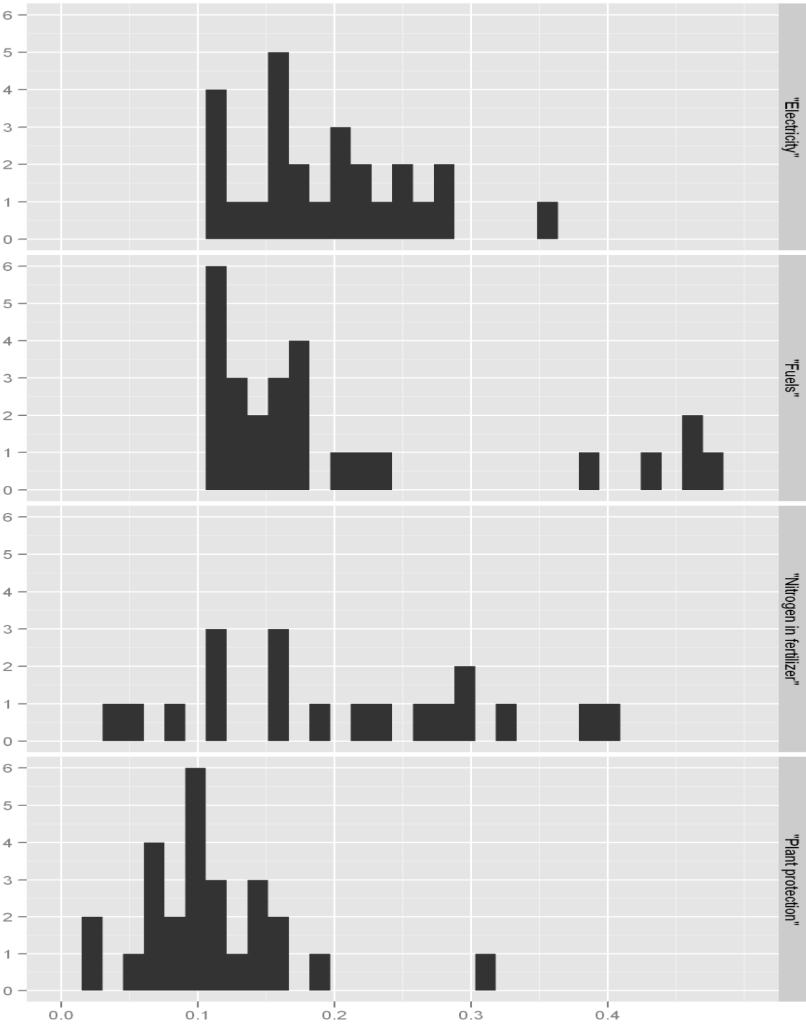
Figure 1: Mean coefficients of variation at EU-27 aggregated level




Source: own calculations based on CoCo data (see input definitions in Table 1)

There are significant regional differences in the volatility of input prices. The histogram in Figure 2 demonstrates how the volatility varies across the EU Member States. The calculated CoVs for plant protection, for example, are close to 0.1 for most of the countries, while CoVs for fertilizer costs seem to be extremely affected by regional differences.

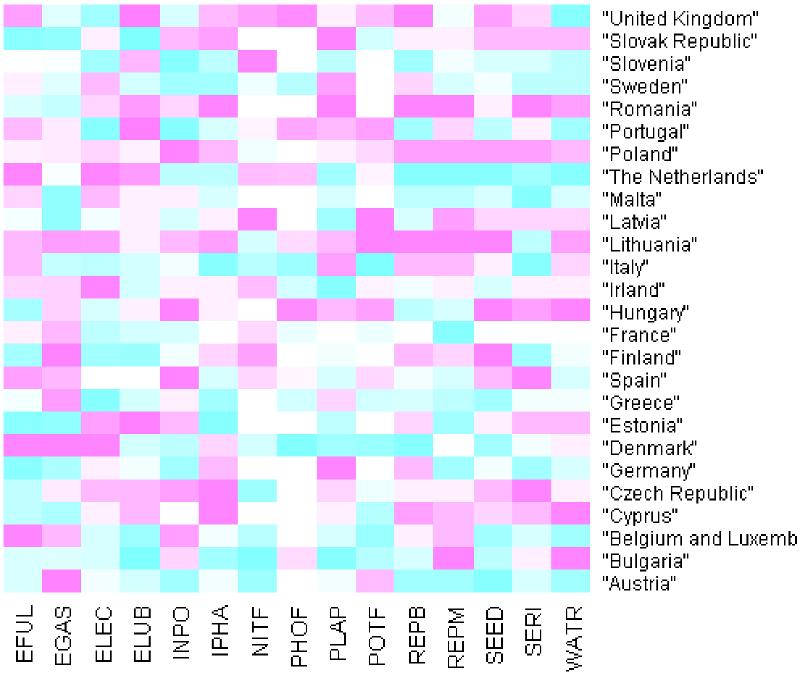
Figure 2: Distribution of coefficients of variation for selected cost items (histogram)




Source: own calculations based on CoCo data

Our analysis could not identify countries which are generally exposed to higher or lower volatility (significantly different CoV for all or at least for most of the inputs). The heatmap in Figure 3 illustrates this finding. Before putting the CoV values on the heatmap those are first scaled by replacing them with the respective percentiles (from 1st to 10th). The colour scale goes from light blue to purple, warmer colours indicating higher values. Missing values result in white cells. If countries with generally higher volatility existed then this would show up as horizontal lines with the same colour on the heatmap. Such coloured lines are, however, hardly observable, suggesting that the regional distribution of volatility differs from one input category to the other.

Figure 3: Heatmap of coefficients of variance by Member States and cost categories




Source: own calculations (see input definitions in Table 1)

## 3. APPLIED METHOD: SCENARIO ANALYSIS WITH THE CAPRI MODEL

CAPRI is a comparative static partial equilibrium model, focusing primarily on the EU27 countries but covering the global agricultural commodity markets as well (Britz and Witzke 2011). The model is built of a number of regional programming models and a global equilibrium model for the agricultural commodities. These parts are linked through an iterative process; the regional programming models provide the supply response under fixed commodity prices coming from the market model. The regions closely follow the NUTS2 administrative regions[6]; the market model covers ca. 40 countries or country blocks.

CAPRI incorporates a detailed nutrient flow model per activity and per region which includes a balancing between nutrient needs and availability through an accounting scheme for feeds and fertilizers. CAPRI also includes a young animal market model which is part of the iterative process explained above. The young animal market model covers trade of calves, young bulls, piglets and lambs between the Member States and provides prices for determining the costs of animal purchases during the simulation.

[6] The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the European Union. The classification is established by regulation EC 1059/2003

In CAPRI farmers follow a profit maximizing behaviour and they base their decisions concerning land allocation and animal production on the relative profit margins. Assuming increasing input costs under ceteris paribus conditions, profit margins shrink and the relative margins change; directly affecting land allocation, animal production and input use. Agricultural production in total declines, however with significant regional differences in scale. Decreasing total supply drives up equilibrium prices, in general, and has a significant effect on trade balances.

Feed costs and young animal purchases account for most of the variable costs in animal production activities and are important drivers of cost-volatility (European Commission, 2011). The CAPRI modelling approach, however, does not allow for applying a direct exogenous shift in the prices of these inputs. Therefore, our scenario assumptions do not include any change in these input prices.

In CAPRI feed allocation follows a cost minimization approach. During simulation the model finds the optimal cost-minimizing feed mix that also satisfies the nutrient balances. Prices of the tradable feedstuff are defined by the equilibrium prices on the commodity markets. The use of non-tradable fodder is fully determined by the nutrient balancing equations: the requirements for energy, crude protein and minimum dry matter intake of animal activities must meet the content in the optimal feed mix. This model setup makes impossible to develop scenarios with exogenous changes in feed prices. Those are endogenous variables of the model and their development depends totally on the internal mechanisms of CAPRI.

Costs of young animal purchases during simulation are defined by the prices provided by the young animal market module. This module of CAPRI simulates market equilibrium for young calves, piglets and young sheep at EU Member States level. Following the same argumentation as above for feeds, developing a scenario with changes in young animal prices was not possible.

Not having exogenous changes in the scenario assumptions, however, does not mean that feed and young animal costs have not changed in our simulations. There are significant indirect effects e.g. on feed costs which are the result of the price feedback of the commodity markets. These are explained in detail in the following sections.

## 4. SCENARIO SETTING

In order to set up a range for the model outcome depending on alternative input cost developments, two scenarios are constructed. One assuming lower, and one assuming higher input prices than what is projected in the baseline. The differences in input prices are relative to the baseline level and the exact percentage changes are defined by the CoV estimations above (differentiated by region and by activity). The scenarios apply the same direction of price changes (increase or decrease) in all regions and for all inputs considered.

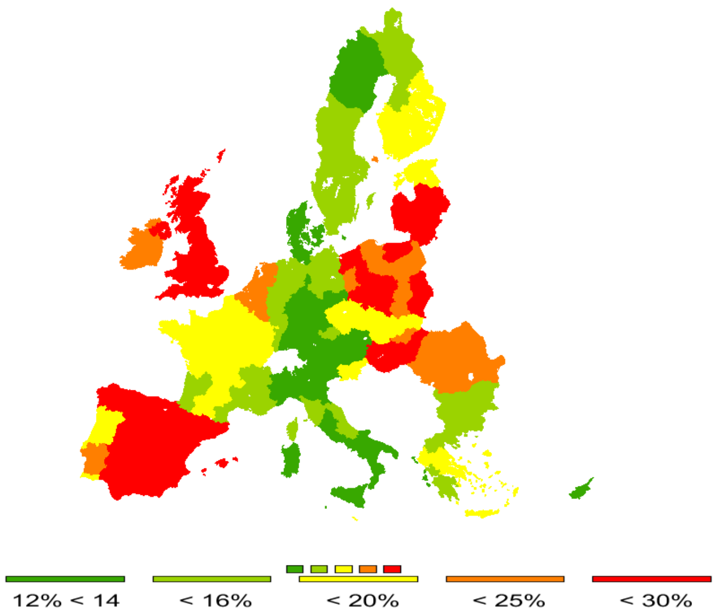
The authors are aware that the two scenarios might not mark the real maximum and minimum levels of the model's output in respect to the full uncertainty in input prices. In particular combinations of the input vector space the model might produce outputs that are out of the range set up by the two scenarios. The approach of our scenario analysis that assumes the same direction of price changes for all inputs and regions is a simplified one. The assumption neglects the effect of possible (negative) correlations between cost items. These issues can be addressed by systematic uncertainty analysis, e.g. in the manner of (Saltelli et. al, 2008). One alternative is to perform parametric bootstrapping on the input price variables. This requires fitting a distribution model and then drawing correlated random samples from the input space. Such Monte-Carlo techniques are, however, difficult to perform with CAPRI, given its size and relatively long solution time and therefore out of the scope of this paper.

## 5. SCENARIO RESULTS

### *5.1. Impacts on the costs of production*

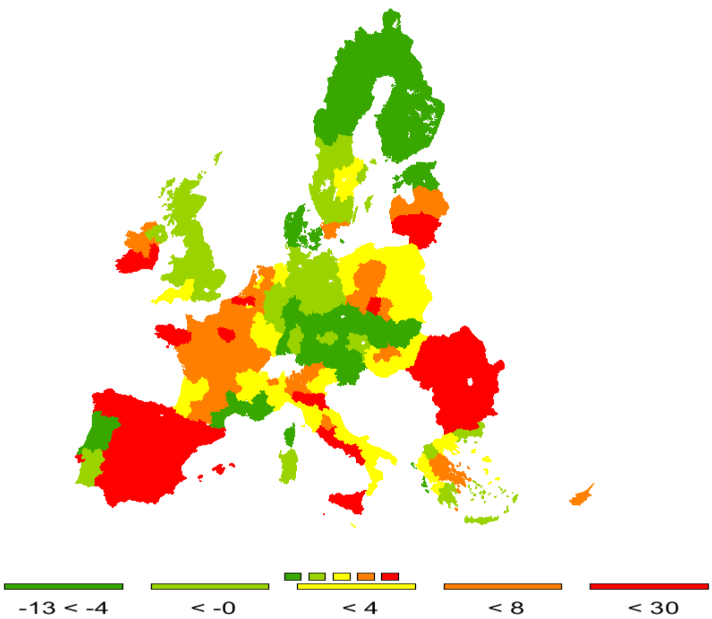
The scenario assumptions induce a symmetric increase in variable costs over the cereals and oilseeds sectors. The EU-27 average change in total variable costs is around +/-18% for both for cereals and oilseeds. There are significant regional differences however (see Figure 4). In the higher cost scenario some regions suffer a 30% increase in costs which is almost three times as high as in many other regions. As explained in section 2.2, the biggest price volatility in our scenarios is assumed for fertilizers, fuel and energy. Therefore the impact is the highest in those regions and for those production systems where the share of these inputs in total input use is the highest or where the calculated CoV figures are above the EU average. Spain is an example for the previous one having a share of fertilizer costs above the EU average. U.K, on the other hand, is particularly affected due to the relatively high estimated volatility of fuel and fertilizer prices; although the share of these inputs in total input use of cereals production is close to the average (Figure 5).

Figure 4: Variable cost increase in the higher cost scenario for cereals (percentage change compared to baseline levels, year 2020)




Source: own calculations

Figure 5: Share of fertilizer costs in total variable costs of cereals production (difference in percentage points from the EU-27 average, baseline, 2020)




Source: own calculations

Livestock production is clearly less effected in the scenarios than cropping activities. The lower input cost scenario, for example, results in a decrease of -2% to -19% in total variable costs (projected to the hectare or number of heads). The cost decrease in the poultry sector (-6%) is higher than the reduction in the beef sector (-2%). The magnitude of the impacts in the second scenario is similar but pointing to the opposite direction. Variable costs in the livestock sector are dominated by the feed cost and the purchase cost of young animals. As explained in section 3, these inputs undergo only an indirect price-effect. Therefore, the impacts in the livestock sectors depend largely on how much the cost structure is defined by those other specific and general inputs that are subject to a direct price decrease in the scenario (energy, maintenance, pharmaceutical inputs, etc.). The larger the share of the purchase cost of young animals, the lower the impact is on total costs.

### *5.2. Commodity balances*

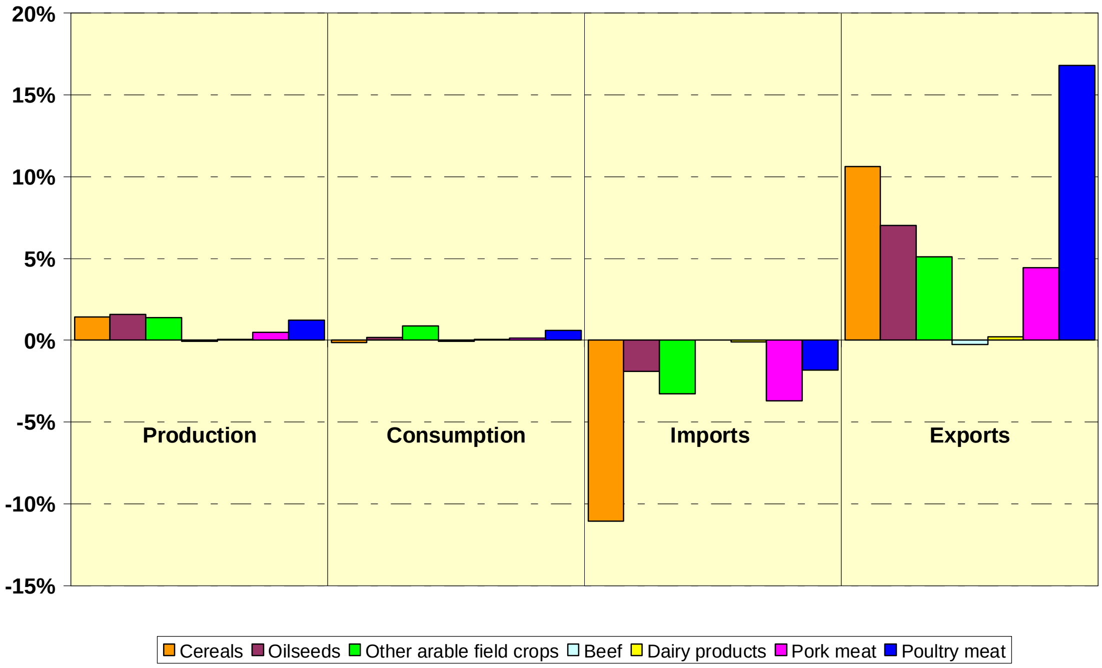
As already noted, changes in the relative profit margins of the agricultural activities induce an adjustment in crops and animal production in CAPRI.

In the lower input cost scenario, due to the profit margin increase, total production of cereals and oilseeds in EU-27 increases by 4.4 mio tons (1.4%) and 511 ktons (1.6%) respectively. Other arable field crops increase by 630 ktons (1.4%), mainly due to potatoes (see Figure 6). Producer prices for crops drop due to the increase in EU supply and to the relatively inelastic demand. This price decrease makes the EU more competitive on the world market, improving the EU trade balances significantly. Crop exports increase by 5% to 10%, while imports are declining by -2% to -11% (depending on the particular commodity market).

The impact on EU meat and dairy production is relatively small, less than 0.5%; only the change in poultry meat production exceeds 1%. The small impact is due to that feed costs and animal purchases are only indirectly affected in the scenario; knowing that the bulk of the variable costs consists of exactly these two categories the impact on profit margins and supply must be limited. The increase in meat production is channelled to an improved export position; particularly for poultry meat (+17%) and pork meat (+4%).

In the higher input cost scenario, the results are almost identical but in the opposite direction than the previous scenario. On the EU import side, we can observe some more significant increases of cereals by 19% (2.3 mio tons) and poultry meat by 21% (53 ktons).

Figure 6: Commodity balances in the lower input costs scenario (relative changes to the baseline, 2020)




Source: own calculations

### *5.3. Revenues and income*

The cost changes induced by our scenario assumptions have a serious impact on total agricultural income[7]. The decrease in the higher input cost scenario is around -9% while the increase in the lower input cost scenario is somewhat below +10%. This means that ca. 17 billion euros have been put on risk by the input price volatility assumption of the scenarios. This figure is probably underestimated because feed costs and the costs of young animal purchases were only affected indirectly, e.g. through the price feedback of the cereals market.

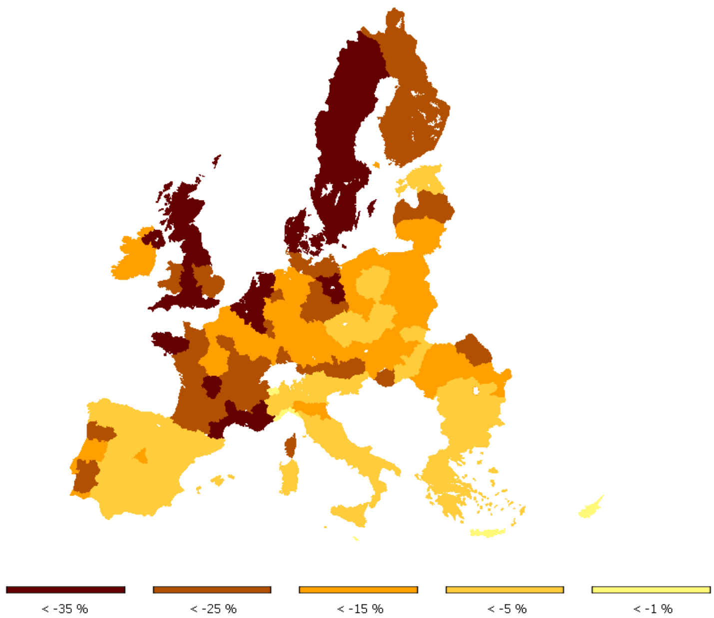
In the higher input cost scenario, revenues of cereals and oilseeds in EU-27 are going up on average by 6% and 8% respectively, largely due to commodity price increase and to an increase of by-product values. Due to the fact that input costs raise at a higher rate, the profit margins of both cereals and oilseeds squeeze: the drop in income reaches -14% for cereals and -9% for oilseeds on average. On regional level the picture is quite diverse (see Figure 7). The most affected regions are those with input-intensive production systems (e.g. the Netherlands and Belgium) and regions with small profit margins (e.g. Portugal). The decrease is most pronounced in regions where both of the above risk factors are present (e.g. Sweden). As

[7] Agricultural income is defined as gross value added at producer prices plus premiums of all production activities in CAPRI. The gross value added definition is in line with the EUROSTAT one and used here as a proxy for farm incomes.

mentioned already above in section 5.1, the high impact on the UK is related to the volatility of input prices, which is above the EU average.

In the lower input cost scenario, revenues of cereals and oilseeds are decreasing to a similar but negative extent (-5% and -6%). Since input costs are decreasing at a higher rate, the profit margins get larger and income increases by 16% for cereals and 12% for oilseeds. Impacts on regional level are very much similar to the high input cost scenario but on the opposite side.

Figure 7: Income change for cereals in the higher input costs scenario (relative changes to the baseline, 2020)




Source: own calculations

In the higher input cost scenario, revenues of the grazing animal activities are increasing. This is due to the combination of a small price increase in dairy prices and a significant increase in the value of manure. Manure is accounted as a by-product of the livestock activities thus contributing to their production values and revenues. The revenue definition above does not include premiums that account for a significant share of income. Thus the change in income in these sectors are much lower than the change in revenues, being e.g. a moderate +3% for dairying and +5% if all cattle activities are averaged out (aggregated EU-27 figures).

In the lower input cost scenario, revenues of the grazing animal activities are slightly decreasing. The beef meat, sheep and goat meat and raw milk prices remain stable. Thus the slight decrease is due to the drop in the value of manure. The revenues of the beef meat activities are -4% lower than in the baseline. Sheep and goat revenues decrease with -1% and -5% for the fattening and for the milk activities respectively.

## 6. CONCLUDING REMARKS

This paper investigates the possible impacts of production cost developments deviating from the trends under normal economic and political circumstances. The selected partial equilibrium model clearly demonstrated its potential to estimate EU-wide impacts on commodity markets and farmers' income. The scenario assumptions, however, have two serious limitations. On one hand, assuming only indirect changes in feed costs and the costs of young animal purchases leads to an underestimation of the impacts in the livestock sector. On the other hand, applying input price increase or decrease only in the EU countries leads to an overestimation of market price effects and of the impact on trade balances.

Feed costs and the cost of young animal purchases could be tackled by combining the above scenarios with appropriate supply and/or demand shocks in the global agricultural markets. Shortage or oversupply of feedstock, for example, might generate significant fluctuations in feed prices with the induced effects in the livestock sector. Addressing the volatility of production costs in non-EU countries first requires information on these costs in a consistent estimation framework. This data requirement seems to be a major burden for extending the analysis in this direction in the near future.

Systematic sensitivity analysis has been already mentioned as a tool for fully explore the uncertainties in input price development and its impact on the model outcome. It remains for further research to investigate its applicability in such large-scale equilibrium models as CAPRI.

Finally, linking the observed input price volatility to its drivers (e.g. oil prices) would put the calculated impacts into an economy-wide perspective, establishing a closer link to agriculture and other sectors in our analysis.

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