Responses of the EU feed and livestock system to shocks in trade and production

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Responses of the EU feed and livestock system to shocks in trade and production

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December 2010

This study was initiated and financed by the Platform Agriculture, Innovation & Society from the Dutch Ministry of Economic Affairs, Agriculture and Innovation. (www.platformlis.nl)

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Abbreviations and acronyms

CAP	Common Agricultural Policy
EC	European Community
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
GMO	Genetically modified organisms
SBM	SoyBean Meal (equivalent)
UAA	Utilised agricultural area

Summary

Food security in the EU has more or less been taken for granted over recent decades, because of the growing agricultural productivity in the EU and elsewhere and the relatively easy import by the EU of agricultural products through the international markets. However, the growth in demand for food by an ever-growing world population may outstrip the growth in production of that food, especially when diets will include more animal products. This may result in lower surpluses in production potential. Combined with the strengthening of the economic power of countries like China and India, which gives them more access to the international agricultural markets, the EU's food system may become more prone to calamities in the agricultural production and food system as there may be less possibilities to 'buy itself out of a problem'.

This report discusses the possible effects on the EU food sector in 2020 of multiple and/or long duration calamities that disrupt trade in and/or production of agricultural products. Examples of possible calamities may be

- a sudden and strong reduction of import of soybean from the America's that will pose large problems for animal production systems;
- severe droughts that reduce arable production, leading to insufficient availability of grain and roughage;
- the occurrence of new diseases in the animal production systems that could lead to very low availability of proteins for human consumption.

The potential of the EU food system to cope with such calamities depends on the level of agricultural productivity in 2020, the available land area for growing crops and fodder, the demand for food and biofuel by the population and the possibility to import food and feed from outside Europe. Expected quantitative trends until 2020 in these underlying causes are described. A model was developed to estimate effects of various types of calamities under these trends. Key characteristics of the model are that it combines an economic module for estimating prices for agricultural products in times of abrupt disruptions in supply with an economic approach to allocate land to various arable products and with biophysical modules for the estimation of animal production. Central in this approach is the emphasis on stocks of products and the rate of change they have with expected/optimal stock size. Produced as well as imported volumes fill the stocks, while consumed and exported products empty them. Since changes in such stocks can be rather fast, the model uses time steps of evaluation of a quarter year in order to reflect better the changes in time of prices, availability of produce, and the adaptations in (specifically animal) production systems. Effects on the EU food systems are described by the model in terms of availability and relative prices of food types (animal products, grains, roughage).

With the model, 7 scenarios were simulated that differ in type(s) of calamity: price shock and import stop of soybean, export stop on grains (only in combination with soybean stop), yield reduction in grains, soybean equivalents and roughage and combination of the latter with stop of import of soybean (Table 1). Results show strong short-term loss of production and increase in prices, often followed by cyclic fluctuations in prices and production caused by overreaction of production on prices. Reduction in availability of roughage has strong short-term and long-term effects on dairy and beef sectors, while shocks in soybean availability/price affect mostly pork, poultry and egg production systems. Higher production within the EU of protein rich crops for biofuel reduces to a certain extent the effects of shocks in availability/prices of soybeans.

The findings of the study indicate that while the EU will have sufficient potential to produce grains to satisfy human food consumption, combinations of calamities in trade and production may result in strong reductions of animal production, with extremely high and volatile prices of these products in

some quarters of the years during and after such calamities. Although in the longer run, agricultural production in EU, also of animal products, may bounce back, specifically the lower income groups in the lower income countries within the EU may face problems in financial and dietary terms as a consequence of calamities.

Table 1 Summary of short term and long term effects on production and prices of simulated scenarios. Scenarios 6 en 7 are with increased biofuel production within EU; implemented by increasing area of soybean (equivalents) with 21 M ha (but with about 40% lower productivity) and grain area reduced by 6.3 M ha

Scenario	Short-term effects	long term-effects
1 soybean price shock: Sudden doubling of price of soybean, thereafter staying at that level	Production of poultry, eggs and pork drops 30, 25 and 20%; Prices of these products 1.3-1.9 times higher	Area of protein crops in EU doubles, grain area reduces 3%; fluctuating prices (higher) and production (lower) of pork, chicken and eggs
2. soybean import stop: No import for two years	Price of soybean (equivalents) increases up to 2.9 fold; production of poultry, eggs and pork drops 50, 10 and 25%; prices up 1.5-2.5 times; 75% reduction in use of soybean and 50% increase of grain in feed	Cyclic fluctuations in production and prices of all animal products; strongest in pork/poultry; lowest in dairy and beef
6 as scenario 2, but with increased biofuel production	*Effects on production and prices of animal products strongly reduced compared to scenario 2; EU production of soybean (equivalents) increases and of grains reduces (affects export only)*	
3 soybean import stop AND grain export stop: No import/export for two years	Similar to scenario 2, but less extreme and in addition lower prices for grains	Similar to scenario 2, but smaller fluctuations
4. yield reduction: 25% reduction for 2 years in availability of roughage, grains and protein crops in EU; free trade in soybeans and grains	Only milk and beef sector respond: milk with 35% production drop and max 1.6 times higher price; beef 40% production increase, price drop of max 10%	Recovery in milk production in 3rd year, of beef in 4th; pork prices slightly higher because of substituting demand for beef
5. soybean import stop AND yield reduction: Combination of scenarios 2 and 4	Milk and beef react slightly stronger than in scenario 4; responses in other sectors similar to scenario 2.	
7 as scenario 5, but with increased biofuel production	*In comparison to scenario 5, effects on pork sector are strongly reduced, while those on other sectors are similar*	

While results indicate that an export stop on grains does not strongly add to resilience of food production in the EU, policy options that may have more potential to reduce the impact of calamities are

- Stimulating larger minimum stocks of grains and specifically soybean (or other protein rich products) than is currently the case
- Promoting co-production of biofuel and protein (for human consumption and/or animal feed)
- Allowing more use of animal products in feed to replace soybean (equivalents).
- Allowing farmers to use roughage from nature and set aside areas to compensate for low roughage productivity due to droughts
- Facilitating credit to livestock farmers, during and after calamities, to prevent large number of farmers going bankrupt and to keep a production base intact

- Developing emergency food rationing systems, specifically dedicated to secure access for low income groups to food during calamities
- Reduction in consumption of traditional animal products in favour of other sources of protein (pulses, insects), e.g. by increasing prices of (certain) animal products (e.g. through taxes) or raising awareness about diets that are healthier and/or more environmentally friendly.

This study focused on a situation where imports of protein could be disrupted, and no trade in animal products took place. In this setting, trade restrictions on inputs have strong impact on consumer prices. Openness to trade in animal products helps in stabilizing the consumer end of the market in case supply of inputs of protein is disrupted.

The dependence on imported protein exposes the European industry to the world market and to possible disruptions in trade. At the same time, large-scale trade reduces the exposure to (regional) shocks in production.

Samenvatting

Vanwege de groeiende landbouwproductiviteit in de EU en elders, in combinatie met de relatief gemakkelijke import door de EU van landbouwproducten van internationale markten, is in recente decades de voedselzekerheid in de EU als min of meer gegeven beschouwd. De groei in vraag naar voedsel vanuit een steeds toenemende wereldbevolking zou echter de groei in productie van dat voedsel kunnen overtreffen, zeker wanneer het gemiddelde dieet meer dierlijke producten gaat bevatten. Dit kan leiden tot lagere voedseloverschotten op wereldschaal, zeker in combinatie met de betere toegang tot de wereldmarkten van landen als China en India als gevolg van het groeien van hun economische macht. Zelfs wanneer er in absolute zin nog geen voedseltekorten zijn op wereldschaal, kan dit ertoe leiden dat de voedselzekerheid binnen de EU gevoeliger wordt voor calamiteiten in de landbouwproductie, de voedselindustrie en de internationale handel, met minder opties voor de EU om zich 'uit de problemen te kopen'.

Dit rapport gaat in op de mogelijke effecten van meervoudige en/of langdurige calamiteiten die de beschikbaarheid van landbouwproducten verminderen op de Europese voedsel- en voersector in 2020. Voorbeelden van zulke calamiteiten zijn

- Een plotselinge en sterke vermindering van de import van sojabonen uit Noord en Zuid-Amerika, met mogelijkerwijs problemen voor de dierlijke productiesystemen in de EU;
- Het optreden van extreme droogtes, met als gevolg een sterke reductie van de productie van granen en ruwvoer;
- Het verschijnen van agressieve dierziektes waardoor de beschikbaarheid van dierlijke proteïnen voor menselijke consumptie plotseling sterk vermindert.

De mate waarin de EU met zulke calamiteiten kan omgaan, hangt af van de productiviteit in de landbouw in 2020, het areaal dat beschikbaar is om gewassen en veevoer te produceren, de vraag naar voedsel en bio-brandstoffen en de mogelijkheid om voedsel en veevoer van buiten Europa te importeren. Verwachte kwantitatieve trends tot 2020 in deze onderliggende factoren zijn beschreven in dit rapport. Een model is ontwikkeld om de effecten te kunnen schatten van verschillende typen calamiteiten bij verschillende trends. Kenmerkende karakteristiek van het model is dat het een economische module voor het schatten van prijzen van landbouwproducten tijdens plotselinge vermindering in de beschikbaarheid daarvan koppelt aan een economische benadering van landgebruikveranderingen (m.n. betreffende akkerbouwgewassen) en aan een biofysisch model voor de schatting van dierlijke productie. Centraal in deze benadering staat de nadruk op voorraden van producten en de snelheid van verandering in die voorraden ten opzichte van een verwachte of optimale grootte van de voorraden. Voorraden nemen toe vanwege aanbod van binnen de EU geproduceerde en/of van buitenaf geïmporteerde goederen, terwijl voorraden afnemen vanwege consumptie en/of export. Omdat de veranderingen in de voorraden soms snel kunnen verlopen, worden in het model per tijdstap van één kwartaal (3 maanden) de veranderingen berekend in prijzen, beschikbaarheid van producten en aanpassingen in de productiesystemen (en dan vooral die van dierlijke producten). Effecten op het voedsel- en voedersysteem van de EU worden beschreven in termen van beschikbaarheden en relatieve prijzen (t.o.v. van startprijs) van verschillende producten (van dierlijke oorsprong, granen en ruwvoer).

Met het model zijn 7 scenario's doorgerekend, die verschillen in type calamiteit (zie Tabel 1). Resultaten laten vooral een snelle afname zien van de productie in de dierlijke productiesystemen na de start van een calamiteit, met sterke prijsstijgingen van dierlijke producten. Vaak worden op de langere termijn daarna cyclische fluctuaties in productie en prijzen gesimuleerd als gevolg van overreacties van de productiesystemen op hoge en lage prijzen. Een vermindering in de beschikbaarheid van ruwvoer kan sterke effecten hebben op de melk en rundvlees sectoren, zowel op de korte als op de lange termijn. Verminderde beschikbaarheid en/of hoge prijzen van

sojabonen hebben vooral effect op de productie van varkens- en kippenvlees en eieren. Een hogere productie binnen de EU van eiwitrijke gewassen voor biobrandstoffen zorgt dat deze aan sojabonen gerelateerde effecten minder sterk zijn.

Uitkomsten van de studie geven aan dat de EU de capaciteit heeft om voldoende granen voor humane consumptie te produceren, maar dat combinaties van calamiteiten in handel en productie tot sterke productie-verminderingen in de dierlijke productiesystemen kunnen leiden, met extreem hoge en zeer volatiele prijzen voor dierlijke producten in een aantal kwartalen gedurende en na een calamiteit. Op de langere termijn keert de productie van plantaardige en dierlijke producten binnen de EU terug naar het niveau van vóór de calamiteiten. Speciaal voor de lage inkomensgroepen in de landen met lagere BNP binnen de EU zouden de calamiteiten echter wel voor (tijdelijke) problemen kunnen zorgen in financieel alsook in nutritief opzicht.

Tabel 2 Samenvatting van korte- en langetermijn effecten op productie en prijzen in doorgerekende scenario's. Bij scenario's 6 en 7 vindt een hogere productie van biobrandstoffen plaats in de EU door een extra areaal van sojaboonequivalenten van 21 M ha (met 40% lagere productiviteit dan sojabonen voor veevoer) terwijl het areaal graan met 6.3 M ha is ingekrompen.

Scenario	kortetermijn effecten	langetermijn effecten
1 sojaboon prijsschok: Plotselinge verdubbeling van prijs die daarna op dat niveau blijft	Productie van kippen, eieren en varkensvlees 30, 25 en 20% lager; prijzen ervan 1.3-1.9 keer hoger.	Areaal eiwitrijke gewassen in EU verdubbelt, graan 3% minder; fluctuerende prijzen (hoger) en productie (lager) van varkensvlees, kippen en eieren
2. sojaboon import stop: Geen import in twee opeenvolgende jaren	Prijs van sojaboon (eq.) 2.9 keer ho-ger; productie van kippen, eieren en varkensvlees 50, 10 en 25% lager; prijzen ervan 1.5-2.5 keer hoger, 75% afname gebruik van sojabonen en 50% toename van granen in veevoer	Cyclische fluctuaties in productie en prijzen van alle dierlijke producten; sterkste fluctuaties bij varkens- en kippenvlees; geringste fluctuaties bij melk en rundvlees.
6 als scenario 2, maar hogere productie van biobrandstoffen	*Effecten op productie en prijzen van dierlijke producten sterk gereduceerd t.o.v. scenario 2; EU productie van sojabonen (equivalenten) neemt toe terwijl graanproductie afneemt (heeft alleen effect op de export)*	
3 sojaboon import stop EN graan export stop: Geen import/export in twee opeenvolgende jaren	Zelfde patroon als scenario 2, maar minder extreme; wel lagere prijzen voor graan	Zelfde patroon als scenario 2, maar minder sterke fluctuaties
4. productiviteitsreductie: 2 jaar lang 25% lagere beschikbaarheid van ruwvoer, granen en eiwitrijke gewassen in EU; vrije handel in sojabonen en granen	Alleen de melk en rundvlees sectoren reageren: melkproductie 35% lager and max 1.6 keer hogere prijs; rundvlees 40% hogere productie, prijsverlaging max 10%	Herstel melk productie in 3e en rundvlees in 4e jaar; prijzen van varkensvlees een beetje hoger omdat het als substituut voor rundvlees wordt gebruikt
5. sojaboon import stop EN productiviteitsreductie: Combinatie van scenario's 2 en 4	Melk en rundvlees reageren iets sterker dan in scenario 4; andere sectoren reageren als in scenario 2	
7 als scenario 5, maar hogere productie van biobrandstoffen	*In vergelijking tot scenario 5 zijn de effecten op de varkensvlees sector sterk gereduceerd; andere sectoren reageren als in scenario 5.*	

Waar de resultaten aangeven dat een export stop op granen niet veel bijdraagt aan de veerkracht van de landbouwsector in de EU, zijn er andere beleidsopties die meer potentieel hebben om de impact van calamiteiten te verminderen:

- Stimuleren van grotere minimum voorraden van graan en met name sojabonen (of andere eiwitrijke producten voor veevoer) dan momenteel gangbaar is.
- Bevorderen van co-productie van biobrandstoffen en eiwitten (voor humane en/of dierlijke consumptie)
- Toelaten van meer dierlijke producten in diervoer ter vervanging van sojaboon (eq.).
- Toestaan dat producenten ruwvoer uit natuurgebieden en uit productie genomen landbouwgrond gebruiken om ruwvoer beschikbaarheid bij sterke droogte op peil te houden.
- Faciliteren van krediet aan producenten van dierlijke producten tijdens en na calamiteiten om faillissementen te voorkomen en een zekere productiebasis in stand te houden.
- Ontwikkelen van systemen voor rantsoenering van voedsel in noodtoestanden, met specifieke aandacht voor het zekerstellen van toegang tot voedsel voor lage inkomensgroepen tijdens calamiteiten.
- Stimuleren van het vervangen van traditionele dierlijke producten in het voedsel door andere eiwitbronnen (peulvruchten, insecten), bijvoorbeeld door verhogen prijzen van (bepaalde) dierlijke producten (via belastingen/heffingen) of het bevorderen van de keuze voor gezondere en milieuvriendelijker diëten.

Deze studie richtte zich op een situatie waarin de import van eiwitten (sojabonen) plotseling gestopt kan worden en er feitelijk geen handel vanuit / naar de EU in dierlijke producten is. In een dergelijke situatie kunnen handelsbelemmeringen een sterke impact hebben op prijzen voor consumenten. Een vrije handel in dierlijke producten, kan helpen om de consumentenmarkt te stabiliseren wanneer aanvoer van eiwitrijke producten voor diervoer stokt.

1 Introduction

Currently, Europe is self sufficient in nearly all basic food items, and even capable of exporting various agricultural commodities. Two major exceptions are vegetable oils and soybean, for which the EU is import-dependent. Former studies (Bindraban *et al*., 2008, 2009), where effects of single and one-off calamities on food production were analyzed, indicate that the food situation most likely will remain virtually unchanged towards 2020, even under a scenario of trade liberalization. Even a disruption of soybean imports, which in itself would reduce meat and milk production, and possibly result in diet change, would not endanger food security in terms of nutritional needs.

As such, the European food system seems rather robust in terms of food availability, with surplus domestic production and strong purchasing power to acquire food on the international market. However, trends such as climate change, increasing world population, increasing per capita consumption of meat, increasing demand for biofuels and a reduction in the supply of phosphorus (e.g. Vaccari, 2009) may tighten the supply and demand balance after 2020, resulting in smaller buffers to withstand fluctuations in supply. This could make the European food system less resilient, especially when food and fodder production in addition is affected by a combination of two or more different types of calamities and/or through a sequence of calamities. This was in effect one of the major conclusions drawn from the '*Workshop voedselzekerheid in de EU: Verkenning van mogelijke calamiteiten*' [Workshop on food security in the EU: Exploration of potential calamities], organized by Stuurgroep Technology Assessment; 20 April 2009.

This report describes the results of a study, commissioned by the 'Stuurgroep Technology Assessment'[1] (TA) of the Dutch Ministry of Agriculture, Nature and Food Quality (LNV), into the possible effects of such combinations of calamities on food security in the EU and resilience of the EU agricultural food production.

The study focused on the consequences of variability in the availability of food and fodder on prices and on the possibilities to feed human population and to maintain animal production, and specifically on the following questions:

- What are the effects of individual or a combination of calamities that reduce the production and/or import of food and fodder on the availability and pricing of food for human consumption in the EU?
- To what extent can increasing the size of stocks of critical food (and fodder?) items reduce the effect of calamities?

Because of the many interactions between the various factors as well as the time dependency of several of these interactions, a model was developed to provide answers to these questions. This model has a focus on the changes during and directly after a calamity in production, consumption and prices of a limited set of agricultural products: grains, roughage, soybean equivalents, milk, beef, eggs, chicken meat and pork. To model the time-dependency of production, consumption and prices, the model has a time-step of calculation of 3 months. Consequently, the simulated course in time of these variables and of the size of the various stocks is a direct result of the interactions described in the model. Chapter 5 gives a general description of the model and how it is used. A detailed model description is given in Appendix II.

Chapter 2 summarizes current land use and productivity of selected crops in the EU, as well as possible future trends in productivity; Chapter 3 does the same for animal production systems. Appendix I gives more details on these issues.

[1] Currently known as ' LNV Platform Knowledge and Society'

Chapter 4 depicts possible changes in demand for food depending on expected population size and potential changes in diet of that population. Chapter 6 provide results of the model, which are discussed in Chapter 7. Finally, Chapter 8 lists conclusions and recommendations.

2 Land use and Production in the EU of cereals, soybean and fodder

2.1 Present situation

Of the total 432 million hectares EU-27 territory, 90% is taken up by rural areas, with 184 million hectares (43%) as utilised agricultural area (UAA) in 2005 (see section 1). Majority of the UAA (59%) is arable land, 34% are under permanent grassland, while set-aside land is around 7 million hectares, or 3.8% of UAA.
Average area and productivity of selected arable crops is given in Table 3.

Table 3 Area and productivity of selected arable crops in 2005 in the EU-27.

Crop	Area (mio ha)	Average yield (t/ha)
Cereals – total	51.5	4.9
Wheat	23.3	5.3
Barley	13.1	4.0
Maize	6.1	7.8
Silage	5.2	
Pulses/protein crops	1.4	
Soy	0.4	2.7

Source: *Eurostat*

For several agricultural products, the EU 27 is near or above 100% self-sufficiency, but specifically for soybean products, the EU is almost 100% depending on imports (Table 4).

Table 4 EU-25 / EU 27 self-sufficiency, selected crop products, 2005/06 (%)

Durum wheat	88.0
Common wheat	103.5
Sunflower oil	52.0
Rape seed oil	92.0
Soybean oil	5.0
Soybean Cake & equivalent	2.0

Source: *Agriculture in the European Union Statistical and Economic Information 2007*; http://ec.europa.eu/agriculture/agrista/2007

2.2 Trends in productivity of crops and grasslands

2.2.1 Effects of trends in climate change, CO_2 concentration and technology development

Cereals
Yields of major European crops have steadily increased since the 1960s, which has largely been due to technology development. The steadily increasing CO_2 concentration in the air is another factor that may affect crop productivity, while climate change, manifested in rising temperatures and changing rainfall patterns, is becoming a factor that increasingly may play a role in changing productivity of crops and grasslands.

Ewert *et al*. (2005) modelled changes in crop productivity, accounting for effects on crop productivity, due to climate change, increasing CO_2 concentration and technology development that are known as the most important drivers of productivity change (Table 5). These effects reflect

the average impact of such changes. As one particular effect of climate change, extreme events, such as long term and severe droughts and heavy rainstorms, are expected to occur more frequently than before. In our approach, these extreme events are treated as calamities (section 5.2).
As wheat is by far the most important food crop in Europe, it is considered as reference crop and relative changes in its productivity are assumed to hold also for other crops and forage.

Table 5 Estimated relative changes in wheat productivity compared to 2005 as affected by changes in climatic conditions, CO_2 concentration and technology development for different scenarios of the IPCC Special Report on Emission Scenarios (Ewert et al., 2005).

Factor	Year	Scenario			
		A1FI[a]	A2[b]	B1[c]	B2[d]
Climate	2020	0.99	0.99	1.01	1.00
	2050	0.98	0.97	1.00	0.99
CO_2	2020	1.04	1.04	1.03	1.04
	2050	1.16	1.13	1.09	1.11
Technology	2020	1.37	1.37	1.30	1.20
	2050	1.87	1.81	1.63	1.28
All factors	2020	1.41	1.40	1.34	1.25
	2050	2.01	1.92	1.72	1.37

[a] Global economic and fossil fuel intensive world; [b] Regional economic world; [c] Global environmental world.
[d] Regional environmental world.

Grasslands
Grasslands will differ in response to climate change depending on their type (species, management, soil type). In general, intensively managed and nutrient-rich grasslands will respond positively to increases in both CO_2 concentration and temperature, provided that water supply is sufficient (Thornley and Cannell, 1997; Lüscher *et al*., 2004). Nitrogen-poor and species-rich grasslands, which are often extensively managed, may respond differently to climate change and increase in CO_2 concentration, while their short-term and long-term responses may be completely different (Cannel and Thornley, 1998). Management and species richness of grasslands may increase their resilience to change (Duckworth *et al*., 2000).
Fertile, early succession grasslands have been found to be more responsive to climate change than more mature and/or less fertile grasslands (Grime *et al*., 2000). Generally, productivity of European grassland is expected to increase (Byrne and Jones, 2002; Kammann *et al*., 2005).

Since no concise quantitative estimates for changes in grassland production were found in literature, here similar relative changes in future productivity are assumed as for wheat.

2.2.2 Effects of trend in phosphorus availability

Until recently, studies on expected future productivity of crops and grassland generally did not pay attention to possible effects of a reduced availability of phosphorus (P). Lately this has changed, and potential P shortages are being discussed, e.g. in the report by Smit *et al*. (2009), who argue that due to lack of sufficient easily available sources for P, shortages may start to occur from 2050, with strongest effects occurring from 2080 onwards. Clear estimates for effects of P shortages on crop production are not provided, among others because of lack of insight in the changes in availability of P relative to requirements and in the increases of price for P fertilizers. Apart from possible changes in (access to) P deposits, also the unknown potentials regarding recycling of P play a role in this uncertainty.

In agricultural production, P is also used as additive to animal feed to enhance the feed conversion efficiency and the build-up of skeletons by the animals. When lower P levels in feed reduce the feed conversion efficiency, more feed will be required to produce the same amount of animal products. However, no literature was found to get insight into the question whether P shortage would reduce the P content of feed, nor whether possibilities to re-use animal bones as source for P in feed will become acceptable (again). Therefore, this aspect of P shortage is left out of this study.

Taken into account for this study, are tentative estimates of effects of P shortage on productivity of crops and grass are introduced (Table 6), which vary according to assumptions for 2020 and 2050 regarding

1. population pressure and consumption pattern to reflect the intensity of food production and the type of food that is produced as a driver of the rate of using available resources of P
2. amount of biofuel produced within Europe: autarchy where all required biofuel is produced within Europe and import where large part is imported; biofuel production uses poses P resources in addition to that used for food and feed production.
3. P-availability: relative high availability, where also currently not exploitable P becomes available and P recycling is relatively successful versus low availability where only current resources can be used.

Table 6 Relative effect of P-availability on arable crop and roughage production

	Year	2020	2020	2050	2050
	P-avail	High	Low	High	Low
Pop & Diet[1]	Biofuel[2]				
Hi_Pop_Hi_pro	Autarchy	0.950	0.900	0.855	0.810
Hi_Pop_Hi_pro	Import	0.970	0.920	0.873	0.828
Hi_Pop_Mod_pro	Autarchy	0.930	0.880	0.837	0.792
Hi_Pop_Mod_pro	Import	0.950	0.900	0.855	0.810
Hi_Pop_Lo_pro	Autarchy	0.910	0.860	0.819	0.774
Hi_Pop_Lo_pro	Import	0.930	0.880	0.837	0.792
Lo_Pop_Hi_pro	Autarchy	1.000	0.990	0.941	0.891
Lo_Pop_Hi_pro	Import	1.000	1.000	0.960	0.911
Lo_Pop_Mod_pro	Autarchy	1.000	0.968	0.921	0.871
Lo_Pop_Mod_pro	Import	1.000	0.990	0.941	0.891
Lo_Pop_Lo_pro	Autarchy	1.000	0.946	0.901	0.851
Lo_Pop_Lo_pro	Import	1.000	0.968	0.921	0.871

[1] Population and Diet: Hi_/Lo_Pop: high respectively low population size estimate; Hi_/Mod_/Lo_pro: high, moderate and low amounts of protein in diet; [2] Biofuel: Autarchy: all crop produce needed for EU target of biofuel use are produced within EU; Import: large part of the biofuel is imported from outside EU.

3 Livestock production

3.1 Current situation

While currently having to import about 5% of consumption of beef and veal, the EU-27 is more than self-sufficient in the production of pork, poultry meat and eggs (Table 7).

Table 7 Production, consumption and self-sufficiency of meat and eggs in EU-27 in 2005.

Product group (1,000 t)	Milk	Beef and veal	Pork	Poultry	Eggs
Production EU-27	142.717	8044	21572	11294	7003
Consumption EU-25/27	?	8445	20370	11169	[1]6837
Self-sufficiency (%)	>100%	95.3	105.9	101.1	102.4

1 including 622000 tons eggs for hatching

Source: meat: *EC, 2007*; eggs: *Van Dijk, 2008*; milk: *Eurostat*

In the dairy sector, roughage is the main feed ingredient, while in the other production systems, large amounts of compound feed are used (Table 8). The major ingredient is formed by cereals, with oilseed meals and cakes (including soy) as a good second.

Table 8 EU compound feed production by main ingredient 2003 (1000 T)

Ingredient	Production	% of total ingredients used
Cereals	55.189	44%
Oilseed meals and cakes (inc. soy)	34.033	27%
Co-products from the food industry (e.g. brewers grain, citrus pulp, molasses)	16.608	14%
Minerals & vitamins	3.245	2,5%
Dried forage	2.379	1,9%
Oils and fats	1.861	1.0%
Others (Tapioca, pulses, dairy products, etc)	11.545	9,6%
Total	124.860	100%

Source: *FEFAC Feed & Food Statistical Yearbook, 2003*

As illustrated in Table 9, soybean meal is the most used and preferred protein source in the EU animal feed sector accounting for 68% of total protein material used (in protein equivalent terms).
No other vegetable protein sources used (maize gluten feed, rapeseed meal, dried forage, pulses, or sunflower meal) come near soybean meal in terms of importance, each individually accounting for less than 10% of total proteins used in protein equivalent terms.
This importance of soybean meal reflects its high level of protein in relation to all other, consistent availability and price competitiveness and its higher level of lysine compared to other vegetable-based products like rapeseed meal (giving it a higher level of digestibility). It is particularly attractive as an ingredient for feeds used in the pig and poultry sectors. In the ruminant sector, protein content is less crucial and other meals like rapeseed meal tend to be more readily substituted for soybean.
The relative high fraction of grain and soybean products in the feed is the reason to simulate their production and import in the model. Availability of other products used in feed is assumed unlimited in the model.

Table 9 Use of protein material by the EU animal feed sector 2003 (1000 T)

Protein source	Volume of material used	Volume in protein equivalents	% of the total use in protein equivalents
Soybean meal	32.580	14.415	68%
Rapeseed meal	5.510	1.888	9%
Sunflower meal	3.685	1.106	5%
Copra-Palm meal	2.591	453	2%
Cottonseed meal	544	221	1%
Others (Corn gluten feed, Pulses, Dried forage, Fish meals)	15560	18083	15%
Total	60.470	21.658	100%

Source: *FEFAC Feed & Food Statistical Yearbook, 2003*

3.2 Trends in animal production

Main factors that contribute to the productive and economic performance of animal production systems are

1. efficiency of conversion of feed into product in relation to quality of the feed
2. maximum/optimal production per animal under optimal diet
3. optimal composition of feed (fraction roughage, protein)
4. losses of animals during the production cycle
5. effective reproduction rate

Various studies show that differences in these characteristics exist between countries, breeds, herds and individual animals. These differences are partially related to management, e.g. care/hygiene, milking frequency, slaughter weight, and partially to genetic potential of the animals, e.g. daily volume of feed intake, efficiency of digestion of feed, fertility, milk production capacity (e.g. Beever & Doyle, 2007; Bereskin *et al*., 1976; Britt *et al*., 2003; Fulkerson, 2001; Grainger & Goddard, 2004; Havenstein *et al*., 2003; Hyun *et al*., 1998; Quiniou *et al*., 1999). There is apparently quite some scope for further improvement (see also Johnson *et al*, 2003; McGuirk, 2000; McKay *et al*., 2000; Merks, 2000; Preisinger & Flock, 2000). Historic data may indicate some trends (e.g. Figure 1), but no clear predictions/expectations for future situations were found in literature.

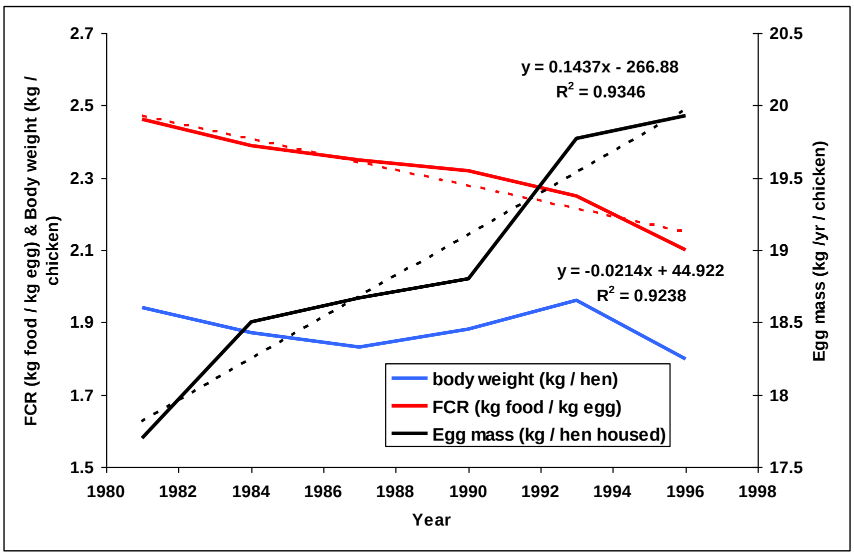


Figure 1 Changes in time of body weight, feed conversion ratio and yearly egg mass-produced for Lohmann LSL layers (data from Preisinger & Flock, 2000). Dotted lines and equations reflect linear regression fits.

In the model, parameters are used to quantify these various characteristics and estimates for parameter values are provided that lay within the range of possibilities (Table 10 until Table 14). An indication of how certain and correct these values are can however not be provided, nor are possible undesirable side effects of breeding for high production efficiency considered (Rauw *et al.*, 1998).

Table 10 Parameters for scenarios for dairy production system

	2005	2020	2020 mod
	Standard	Moderately efficient	Highly efficient
Efficiency of conversion of feed into milk (kg milk / kg dw feed of optimal quality)	1.36	1.38	1.40
Maximum production of milk at optimum intake and quality (kg milk / cow / year)	8900	9000	9100
Optimal fraction roughage (dw roughage / total dw feed)[1]	0.735	0.725	0.720
Standard dying rate of animals (per year): calf	0.101	0.085	0.075
-do- heifer	0.019	0.017	0.015
-do- first year cow	0.010	0.0088	0.0075
-do- cow	0.005	0.004	0.003

[1] remainder is taken in by compound feed with 40% grain, 10% soybean and 50% other substances

Table 11 As Table 10 for beef production system

	2005	2020	2020 mod
	Standard	Moderately efficient	Highly efficient
Maximum efficiency of conversion of feed into meat (kg body growth / kg dw feed with 18.6% protein)	0.180	0.185	0.190
Minimum efficiency of conversion of feed into meat (kg body growth / kg dw feed with 4% protein)	0.050	0.055	0.060
Standard dying rate of animals (per year): calf	0.100	0.0875	0.075
-do- heifer	0.040	0.0275	0.015

Table 12 As Table 10 for broiler production system

	2005	2020	2020 mod
	Standard	Moderately efficient	Highly efficient
Maximum efficiency of conversion of feed into meat (kg body growth / kg dw feed with 16.7% protein)	0.600	0.625	0.650
Minimum efficiency of conversion of feed into meat (kg body growth / kg dw feed with 8.2% protein)	0.400	0.425	0.450
Standard dying rate of animals (per year)	0.050	0.045	0.040

Table 13 As Table 10 for egg production system

	2005	2020	2020 mod
	Standard	Moderately efficient	Highly efficient
Efficiency of conversion of feed into eggs relative to standard	1.000	1.025	1.050
Maximum production of egg at optimum feed intake and quality (# eggs/ chicken / year) ≤ 3 mnth	215	252	290
-do- ≤ 12 mnth	227	268	308
-do- > 12 mnth	216	256	295
Standard dying rate of animals (per year): ≤ 6 mnth	0.0360	0.0345	0.0330
-do- ≤ 12 mnth	0.0480	0.0455	0.0430
-do- > 12 mnth	0.0600	0.0440	0.0500

Table 14 As Table 10 for pork production system

	2005	2020	2020 mod
	Standard	Moderately efficient	Highly efficient
Maximum efficiency of conversion of feed into meat (kg body growth / kg dw feed with 15% protein)	0.345	0.352	0.360
Minimum efficiency of conversion of feed into meat (kg body growth / kg dw feed with 10% protein)	0.294	0.302	0.310
Standard dying rate of animals (per year): ≤ 6 mnth	0.050	0.038	0.025
-do- ≤ 12 mnth	0.010	0.008	0.005
Yearly number live piglets produced per sow per year	22.8	23.0	23.5

4 Present and future consumption of agricultural products in the EU

The human population of the EU 27 is expected to grow a little more, from 489 million in 2005, to 496.4 million in 2020. Thereafter, the population will decline, to an estimated 472 million people in 2050 (Eurostat, yearbook 2006-07).

Various visions and scenarios exist about how the diet of the EU-27 citizens may change in the future. While some forecast consumption of animal products to increase further, others hope that the diet will become nearly vegetarian. Weidema *et al*. (2008) forecast EU-average meat consumption to increase by 3.6% from 2001 to 2020, with a 2.6% increase for pork, 14.3% for poultry, a reduction of 6.9% for beef and veal, and a stable consumption of dairy products. Nowicki *et al*. (2007) assume a slightly larger increase of 4.5% per capita from 2005 to 2020, but with less variation between meat types: 6% for pork, 6.4% for poultry and less for beef.

A disadvantage of the above approaches is that they do not provide alternative scenarios that could result from policies or health considerations. The model, therefore, follows the approach as described by Bindraban *et al.* (2009; building upon WRR, 1995) with three scenarios for diet composition: Affluent, Moderate and Vegetarian, varying in daily intake of energy and (animal) protein (Table 15). The Affluent diet, which delivers more than sufficient energy and (animal) protein, is considered the type of diet that people are moving to when having more income to spend on food; as such, it is currently found mostly in rich societies, such as Western Europe and the US. The Moderate and Vegetarian diets provide sufficient energy and protein. Especially in the Vegetarian scenario, increased consumption of pulses will have to compensate for the reduction in animal products. In the Moderate and Vegetarian scenarios, still substantial milk consumption is foreseen, while consumption of beef is strongly reduced. The inherent assumption must be that the EU will start exporting beef under these scenarios.

Table 15 Consumption scenarios for 2020 in comparison to actual consumption in 2005

Year		2005	2020	2020	2020
		Actual	Affluent	Moderate	Vegetarian
Population (million)		489	496.4	496.4	496.4
per capita consumption (kg/person/year)					
	Cereals	171	98.2	179.2	203.7
	Milk[1]	273	365	568	169
	Eggs	13.5	13.1	5.8	1.5
	Beef	17.3	23.4	5.1	0
	Pork	41.6	38.3	2.9	0
	Poultry	22.8	16.8	0.4	0
Total consumption (million kg/year)					
	Cereals	83619	48746	88955	101117
	Milk	133500	181199	282223	84345
	Eggs	6602	6503	2879	745
	Beef	8460	11616	2532	0
	Pork	20342	19012	1440	0
	Poultry	11149	8340	199	0

[1] milk is including industrial milk products (e.g. cheese, butter)
After *Bindraban et al., 2009*

Due to the higher use of agricultural products per capita in the Affluent diet (also due to its high content of animal products), this food scenario will lead to land use and import strategies that are more sensitive to calamities in production or trade than the other two. Therefore, this study assumes the situation that all EU citizens follow the Affluent diet.

5 Model

5.1 General Setup of the Model

Availability of food and fodder is affected by changes in production, imports/exports and stocks of grains, soybean, fodder, milk and meat. Linking these changes to determining factors, like climate, geo-politics, energy prices etc, is considered too complex and hence too time-consuming to be part of this project. Instead, scenarios regarding trends of change in these factors were introduced to the model as external factors. As much as possible, these scenarios were based on existing studies.
To estimate the consequences of changes in these factors, a standardized calculation scheme (in other words, a model) was developed to evaluate additional scenarios with differences in the variability of production, trade and of policy decisions on stock size over a certain number of years (flowchart in Figure 2).

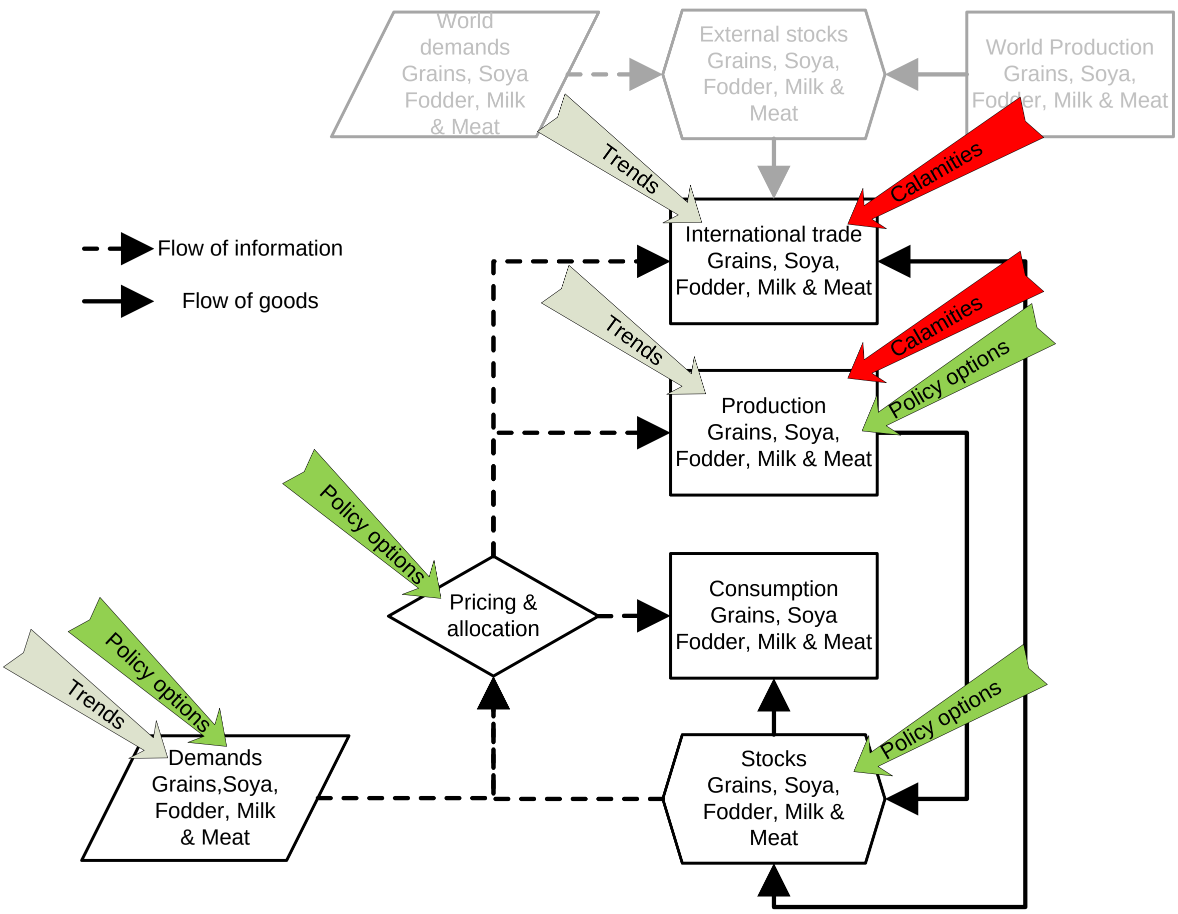


Figure 2 Flow diagram of the model for the quantification of food availability and pricing with variable production, trade and stock size options. Light gray indicates factors not explicitly taken into account but imposed onto the model through trends and scenarios. Arrows 'Trends', 'Calamities' and 'Policy options' indicate factors in which scenarios differ.

In case calculated production cannot meet assumed demand, the model calculates additional volumes required from domestic stocks or the world market. Depending on EU stock volume and possibility to acquire goods on the international markets, prices are calculated of grains, soybean, fodder, and animal products (milk, beef, pork, chicken meat and eggs). A feedback between prices and demand results in a change in demand, varying with the different uses of the various goods, with consequences for calculated consumption and, in the case of grains and soybean, also on the production of animal products. Outcomes of the model are prices and consumed volumes per good per type of 'consumer' (human population, animals, international trade).

Variability in demand, production, trade, stocks, has three underlying causes:

1. Trends in production, trade and demand related to changes in population size, lifestyle, climate, technology (in Figure 2 indicated by the 'Trends' arrow).
2. Occurrence of calamities. Since here the resilience of the food system is studied in situations with shortages of food, only those calamities are taken into account that reduce production and international trade of the goods ('Calamities' arrow).
3. Effects of policy decisions, which here are assumed to only be directed towards the maximum stock size for the goods in Europe. Policy decisions in and outside EU affecting technology development, area of arable land assigned for production of other goods, e.g. for biofuel, demand, etcetera, will be reflected in trends. Policy decisions outside the EU having immediate and strong effect on international trade, e.g. export stop on grains, are introduced as calamities.

In the model, strength of trends and calamities are expressed as effects relative to a baseline situation. In this study, specific sets of strength, duration and recurrence of calamities and trends will be discussed, although in principle the model can handle a wide range of such calamities and trends, differing in the variables mentioned in Table 16.
As baseline serves the liberalization scenario in the EU in 2020 (Bindraban *et al*., 2009), without the effect of a reduced availability of phosphorus.

Table 16 Variables in the model and the underlying assumptions of trends, calamities and policy options to be considered

Variable	Trends	Calamities / policy option
EU production of cereals, soybean, fodder, milk and meat	Climate, technology, availability of phosphorus	Drought, plant diseases, nuclear accident, volcanic eruption
EU demand cereal, soybean, fodder, milk and meat	Population size, diet	None
EU-stocks of cereal, soybean, fodder, milk and meat	None	Stock capacity
Global trade volume , soybean, fodder, milk and meat	Climate, technology, availability of phosphorus, world population, diet	Severe global production reduction, geopolitical constraints, protectionism by exporting countries, failures in transport system

5.2 Scenarios and Calamities

In the model, the combined effect of long-term trends in climate change, CO_2 concentration in the air, technology and P availability is modelled as a continuous change in productivity of crops and grassland, relative to that in 2005, by combining the estimated effects in Table 5 and Table 6. For example, the total effect of climate change, CO_2 and technology in 2020 under scenario A1FI (Table 5) can be combined with the effect of P shortage under the scenario of a high population with a high protein diet and imported biofuel (Table 6). The productivity of crops and grasslands as used in the model will then be 1.41 * 0.970 = 1.3677 times that of 2005.
Similarly, effects of developments in management and genetically determined production potential in animal production systems are taken constant during the whole simulation for a certain scenario for animal production.

These trend values are used during all simulated 'years'.

Calamities are defined in the model as negative effects on productivity or import/export and are only invoked during a certain time in the simulation, e.g. only during year 0 or in years 0 and 1. Causes for calamities are not part of the model, as for the evaluation of a calamity in this study only the effect is important. However, for reference, causes for calamities can be related to adverse weather conditions, such as drought, heavy storms, excessive rainfall and (long) spells of extreme cold or high temperatures, to geological events such as tidal waves that destroy harbours, and volcanic eruptions, to (geo)political decisions that may stop export of soybean to Europe, and epidemics of (new or evolved) animal diseases. See Bindraban et al. (2009) for an overview of such calamities that have occurred recently.

Volcanic eruptions disrupting agricultural production

In historic times, several volcanic eruptions have caused strong reductions in agricultural production. Famous examples are eruptions of Laki volcano (Iceland) in 1783 and Tambora volcano (Sumbawa Island in Indonesia) in 1815. Ash clouds reduced global temperatures and level of solar radiation reaching the surface of the earth thereby reducing crop yields in large part of the world. Acid clouds and rains (caused by emissions of sulphur) destroyed part of the crops. In large parts of Europe, food production was strongly reduced for at least two years, resulting in very high prices for grains and famine, which in its turn caused many riots.

Sources: *Wikipedia and http://www.w8.nl/tambora.htm*

An argument for the relevance of the possibility to introduce calamities that affect crop production in two consecutive years is given by the general agreement that climate change may very well result in more frequent extreme weather events than currently. Even if the cause for the calamity differs between the two years, the effect on crop production could be very similar.
Especially because of the trend in climate change to make the average weather in many places warmer and dryer, extreme events may have strong effects. Crops often respond nonlinearly to changes in their growing conditions and have threshold responses, which greatly increase the importance of climatic variability and frequency of extreme events for yield, yield stability and quality (Porter and Semenov, 2005). As such, an increase in temperature variability will increase yield variability and reduce average yield (Trnka *et al*., 2004). Therefore, the projected increases in temperature variability over Central and Southern Europe (Schär *et al*., 2004) may have severe impacts on the agricultural production in this region. In addition to the linear and nonlinear responses of crop growth and development to variation in temperature and rainfall, short-term extreme temperatures can have large yield-reducing effects (Porter and Gawith, 1999; Wheeler *et al*., 2000). This is particular the case when such temperatures occur during flowering and fruiting periods, where short-term exposure to high temperatures (usually above 35° C; Porter and Semenov, 2005) can greatly reduce fruit set and therefore yield. Exposure to drought during these periods may have similar effects.
Usually, individual extreme events will not have lasting effects on the agricultural system. However, when the frequency of such events increases, production could be more severely affected, especially when such events occur in two sequential cropping seasons.

Calamities that affect crop production are implemented by introducing relative production losses for crops to occur in year 0 and in some cases also in year 1. Those that affect imports (of soybean in particular), are introduced by indicating in which years (0 and possibly 1) such import stop occurs. The model then automatically selects also the relevant pricing mechanism for that situation (see also sections 7.4 and II.1).

6 Results and discussion

6.1 Introduction

The initial settings of production and demand in the model are determined by the trend scenario chosen (section 5.2). Each scenario is composed of expectations of future developments (trends) in consumption and production, which come from different studies. This may result in a scenario where production and consumption are not in equilibrium according to the pricing system that is implied in the model, and it takes the model some simulation ‘years’ before such an equilibrium is achieved. In the standard trend scenario, this is the case about 5 years after initialization of the model (Figure 3).

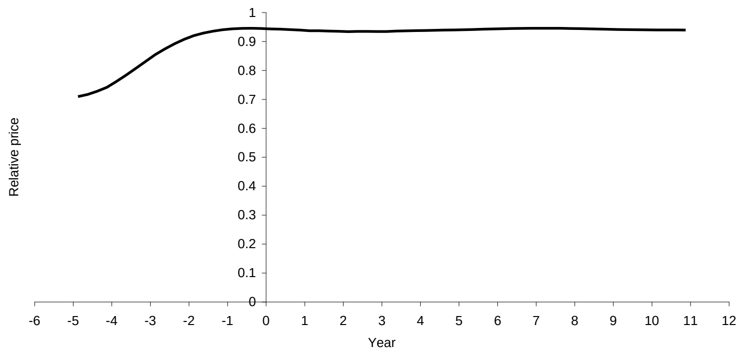


Figure 3 Simulated relative price of beef over the simulated years (year -5 is the start of simulation) in the standard trend scenario.

If a calamity would be introduced directly at the start of the model, evaluated effects not necessarily would reflect only the impact of such a calamity, but also effects of the disequilibrium.
Therefore, the results discussed here refer to the effects of calamities that are introduced after the required equilibrium is achieved. Since the focus of this study is on the effects of calamities, the year 0 in figures and tables refers to the first year that a calamity is introduced.

6.2 Trade and production shocks in the standard trend for 2020

Trade shocks take the form of shocks to prices, but may also be the result of trade disruptions. For the feed sector, prices of grain and soybean (and their substitutes) are important. In the standard trend for 2020, the EU is a net grain exporter and a large soybean importer. Thus, trade disruptions (i.e. no imports, no exports) leave the EU with a surplus of grain and a shortage of soybean.
Even without trade disruptions, the EU can experience trade shocks, for example, due to excessive demand for soybean from outside the EU or reduced production, with the consequence that prices in the world market rise steeply.
The following calamities will be dealt with:

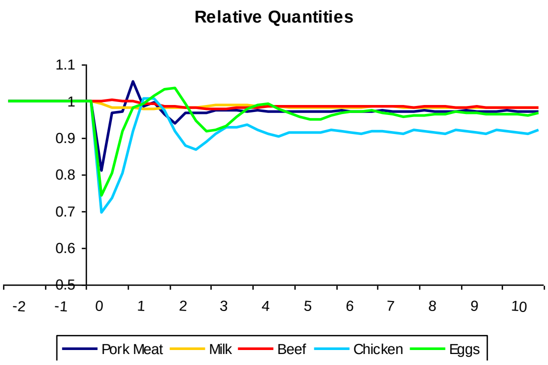
- a sudden and permanent doubling of world market prices
- an import stop on soybean lasting two years and starting in quarter I of year 0.
- an import stop on soybean, and an export ban on grains of the same duration
- a severe yield reduction, e.g. caused by drought or by ash from volcanic eruptions during two years
- a severe yield reduction, combined with import stop on soybean, of two years’ duration

The simulations are made for the situation (population, yields, areas) expected to prevail in 2020. The standard assumption is that the EU is integrated in the world market for grains and soybeans, but not for animal products. Hence, without trade disruptions feed prices in the EU are the same as world market prices. Prices of meat are supposed to be determined inside the EU. Currently, little net exports of meat takes place amounting to approximately 3% of consumption. This percentage is expected to decline by 2020. Hence, while trade is possible, it is uncommon. Sharp falls in production will therefore not easily be met by imports, especially not for fresh products such as milk and eggs. Prices within the EU can go up therefore despite open borders. To have this effect in the model, we assumed no trade to occur at all.

Scenario 1: Soybean price shock

Assumption: world market prices of soybeans shift to twice the original values as of year 0, without affecting the world market prices for grain

The assumption is that world market prices rise to twice the original value, starting from year 0, accounting for increasing elasticities (at fixed elasticities, the price rises fourfold). Demand for soybean will therefore drop. Supply of soybean in the EU will respond, but soybean can only be produced in the third quarter of the year. Grain prices, meanwhile, are assumed to remain steady. The dairy sector will find it advantageous to shift to using grain instead of soybean. For pigs and chicken, such a radical shift is not possible, and their production will be adjusted downward in response to higher feed prices. As a result, the prices of pork, eggs and poultry will rise.



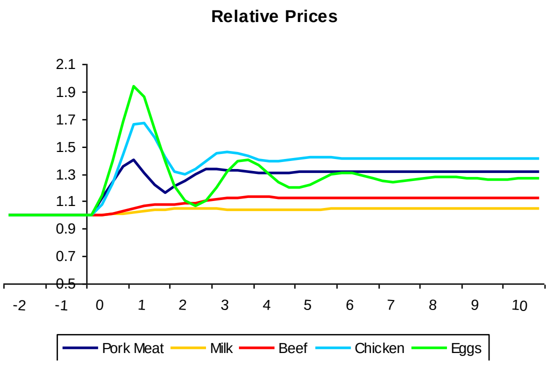


Figure 4 Responses to a 2-fold increase in soybean prices as of year 0; production and prices are relative to those in the standard scenario. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

The area allocated to protein crops almost doubles in response to this price increase, while the grain area falls by 3%. Production of poultry drops by some 30%, while smaller decreases occur in egg and pork production, and milk and beef hardly respond (Figure 4 left). As a result, prices of the pork, poultry and eggs will go up, as shown on the right hand side. The rise of product prices, then, triggers more production and the production of the three types of animal products increases again to levels close to those in the standard scenario. Eventually, equilibrium is reached in which prices of these products are between 25% (eggs) and 40% (poultry) higher than they were, while production quantities are between 4% (eggs) and 8% (chicken) lower.

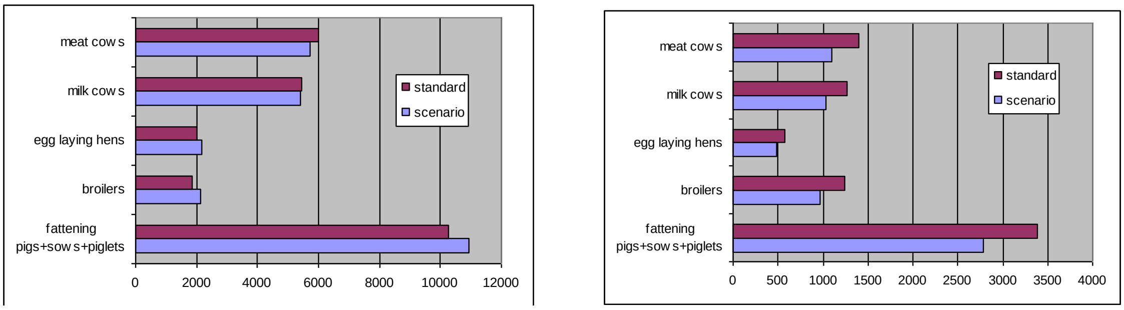


Figure 5 Changes in use of grains (left) and soybean (right) feed (on X-axis) by sector in response to a doubling of soybean prices

Milk production and beef production show little response: there is slightly less milk production, due to the reduction of herd size and a minor change from soybean to grains, and beef prices move to levels that are some 12% higher, due to slightly lower production and the increased demand due to higher pork and poultry prices.
The price shock thus hurts the industry quite strongly in the initial two quarters, mostly due to the slow transmission of feed prices into product prices.

Total demand for soybean will fall by around 20%, while grain feed demand rises by 3%, mostly due to increased demand for grain in the pig and broiler sector (Figure 5). The grain-soybean ratio in the feed for the different animal production systems changes in favour of grains. Taking all sectors together, the ratio changes from 3.26 to 3.9 kg grain per kg soybean.

Scenario 2: Trade disruption in soybean only

Assumptions: no soybean imports possible during the 8 quarters of years 0 and 1, grain trade remains free.

The next simulation shows the results of a stop in imports of soybean (meal) in years 0 and 1. This important ingredient of feed then must be curtailed. Prices shoot up, and availability is also otherwise limited. After year 1, however, trade resumes its normal course, but the effects of the trade shock will linger on for some years as shown in Figure 6.

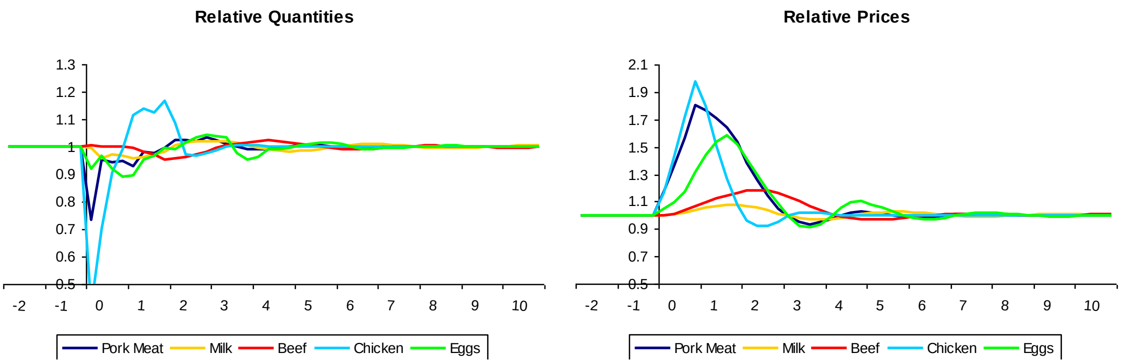


Figure 6 Responses to a stop on soy-imports in years 0 and 1. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

The immediate changes in production of meat are quite severe. To reduce the consumption of soybean (meal) to levels that can be provided from the existing stocks, prices of soybean increase to 2.9 times the initial value (with increasing elasticities) in the first quarter. It reflects the scarcity and incidental unavailability of the feed.

In response to this sharp increase in feed prices, meat and egg production drops and prices of products start rising. These higher product prices leads to a later recovery of meat production. The recovery is quickest in sectors such as poultry, which produces the original quantities again by the fourth quarter, using much less soybean meal (-75%), and more grain (65%). The pork sector is not that flexible, and restores the original levels of production only by the end of quarter 8. As can be seen in Figure 6 (left), the pork production shows a small hick-up in quarter 2. This reflects the delayed supply of pigs that were being fattened when the ban on soybean imports became effective. On average, production of pork during the two years 0 and 1 is down by 7%, while soybean consumption in the sector is reduced by two third.
This shows that the effects of an import ban of soybean are not as severe as tentatively indicated by Bindraban *et al*. (2009), who took a reduction of pork production by a third to be the likely outcome. In the egg sector, the effects are not so strong, and the responses are not so quick, due to the longer natural cycle of the hens, and the more moderate responses to price changes. Again, we see that the effects on the dairy sector are minimal. In this sector, and elsewhere, a shift is made from using soybean (meal) to using grains as feed ingredient. Taking all animal sectors together, the demand for grains increases by 50%. Prices are not affected, as all this grain comes at the cost of exports, and the reduced exports have negligible effects on the world market price, given its small effect on total world trade. In the period after the import ban, it takes another two years before normal conditions prevail again.

Changes in grain and protein use by sector are shown in Figure 7.

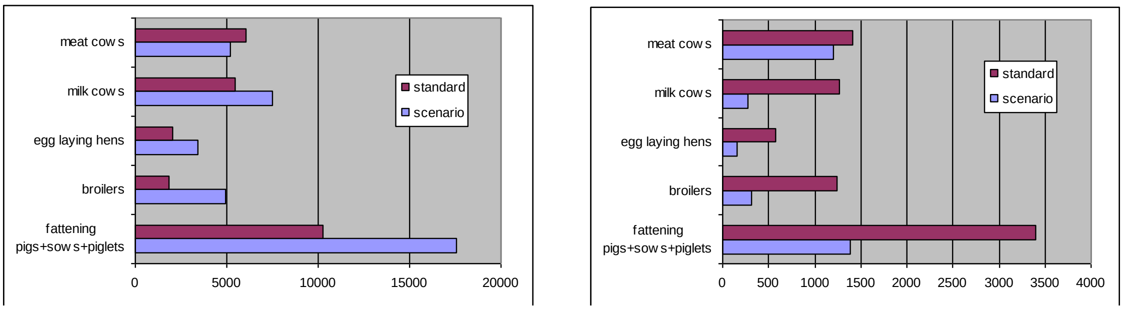


Figure 7 Change in use of grains (left) and soybean (right) feed by sector resulting from soybean import stop

Scenario 3: Trade disruption in soybean and grains

Assumptions: no soybean imports and grain exports possible during the 8 quarters of years 0 and 1.

A further stop on trade in grains, additional to the import ban on soybean, amounts to a ban on exports of grain. This would typically reduce the price of grains, but the lack of soybean leads to increased demand for grains, as we have seen above. In addition, grain production in the years of the trade embargo will respond to the change in prices. Whether this leads to higher prices of grains too, we shall discuss now.
The initial responses to the trade embargo will not differ much from the previous simulation, as soybean price should rise again to choke off the demand for it. Grain now is more easily available, but its prices are only slightly below the normal prices, as stockholders have no incentive to sell the grain very cheaply. (In the model, this is implemented by restricting downward adjustment of prices to 10% per quarter) As this consideration holds for every stockholder, competition will not drive prices down quickly. The lower prices of grain lead to somewhat less sown area in year 0 and again in year 1, with production down by 10% in each year. Grains stock levels will continue to rise during these years, however, leading to ever lower prices of grains.
The effects on meat production and product prices will therefore be slightly weaker than in the previous scenario (Figure 8).

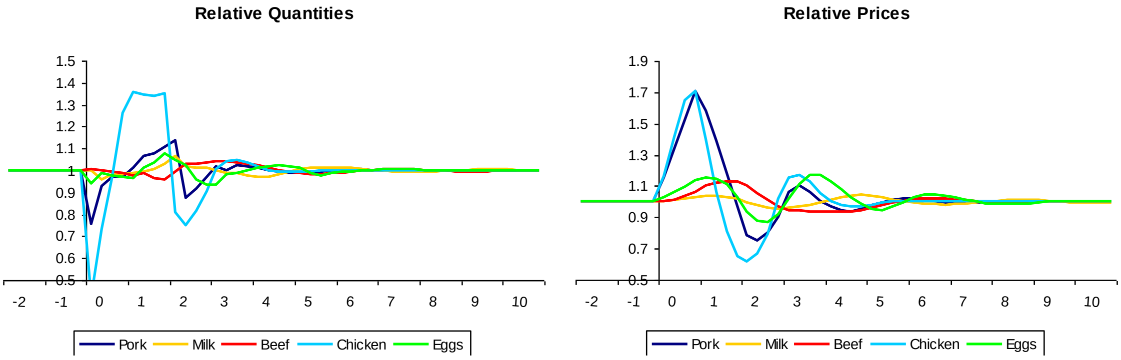


Figure 8 Responses to a stop on soybean imports and grain exports in years 0 and 1. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

The effects on use of grain and soybean can be seen in Figure 9, which shows that grain use in pork sector, for example, more than doubles to compensate for the lower use of soybean and is higher than in Figure 7, where grain was more expensive.

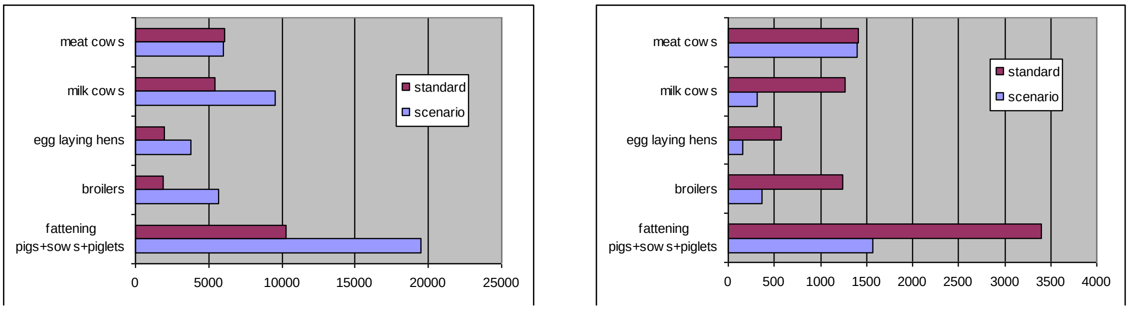


Figure 9 Grain (left) and soybean (right) use in quarter 8 with trade stop/disruption in years 0 and 1

Scenario 4: A yield reduction

Assumptions: effective roughage availability and yields of grains and protein crops fall by 25% in years 0 and 1, free trade in soybeans and grains

We now simulate what the effects would be of a yield reduction only, starting in January of year 0 and lasting until the end of year 1. We assume that prices of grains and soybean remain unchanged and equal to the world market prices of 1, as trade is still possible.

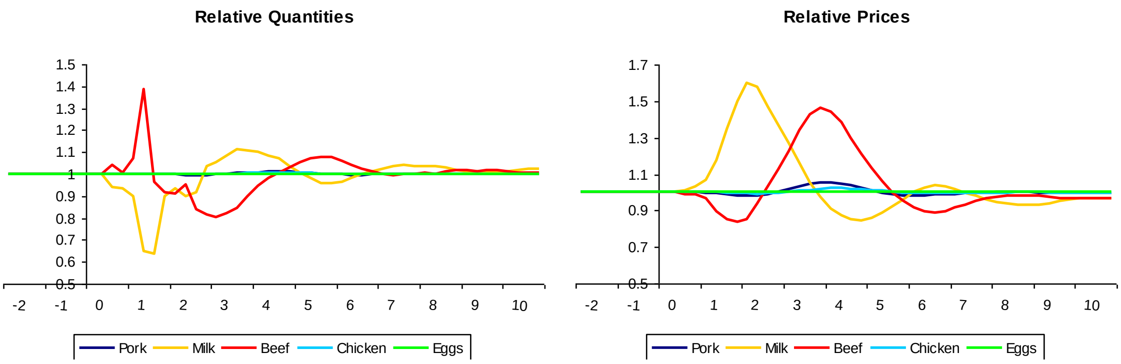


Figure 10 Responses to a 25% yield reduction in years 0 and 1. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

We see that in fact only the dairy sector and the connected beef sector respond to such a shock (Figure 10). A severe shortage of roughage in the first quarter of year 1 leads to culling of cows,

reduced milk production, higher beef supply. Milk prices soar, and beef prices fall temporarily in year 1. When arable production recovers, however, cattle stocks on the dairy farms soon are replenished, not least because of the attractive product prices prevailing in year 3.
The small changes in pork prices shown in the figure are due to the substitution effects between beef and pork: the higher beef prices lead to more demand for pork and higher pork prices.

Scenario 5: Trade disruption in soybean, combined with a yield reduction

Assumptions: Effective roughage availability and yields of grains and protein crops fall by 25% in years 0 and 1, free trade in grains

Here, a reduction of yields is added to the import stop on soybean. This reduction applies to grains, soybean and roughage production. This affects the availability of soybean and grains to the extent that these have to be produced in the EU, while the reduced production of roughage will have strong effects on the dairy sector (Figure 11).

The yield reduction affects roughage production in year 0, but its supply falls short of demand only in the first quarter of year 1. At this point, price of roughage shoots up and demand is curtailed drastically. With no alternative roughage feed available, the only option is to cut in the number of animals to be fed. The shortage of roughage leads to the culling not only of older cows, but also of more productive cows. Milk production drops temporarily by 40%, and beef supply rises as more cows are put up for slaughter. Supply peaks in the second quarter of the second year, at 45% above normal. While milk prices rise (in quarters 3 and 4 to only 3% and 7% above normal, but after the roughage shortage becomes acute, to 13, 28, 51 and 71% above normal in the second year), beef prices first rise (to +6% in Q5) along with pork and poultry, then fall briefly (to -4% in Q7) before rising as a result of reduced beef supply (-28% at the end of year 2) later on.

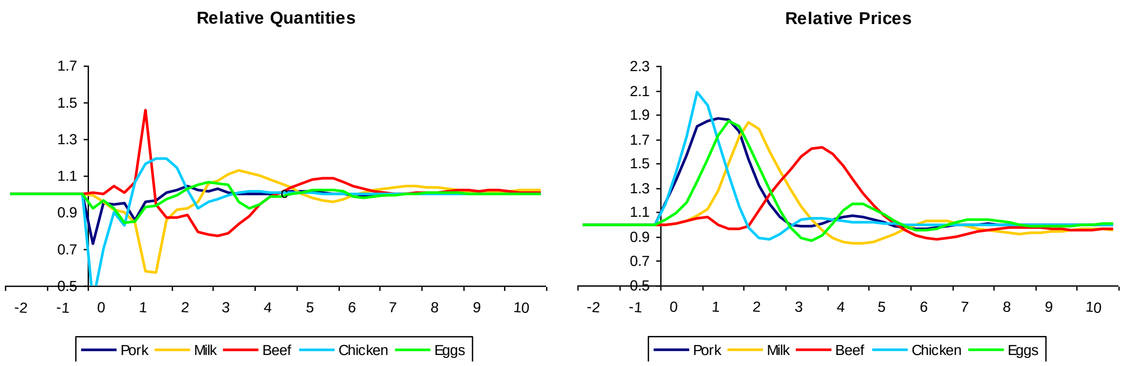
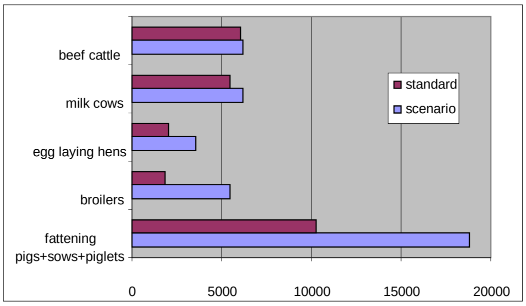


Figure 11 Responses to an import stop on soybean combined with yield reduction in years 0 and 1. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

Effects on the other sectors look similar to the earlier simulations with an import stop only. Soybean prices are somewhat higher, at 3.23, because of the low production within the EU, hence meat production is cut even more. In the first quarters chicken production is reduced to 41% (Q1) and 70% (Q2), pork production in Q1 shrinks by 27%, but the annual total pork production for the first year is reduced by 11% only (for poultry 29%).



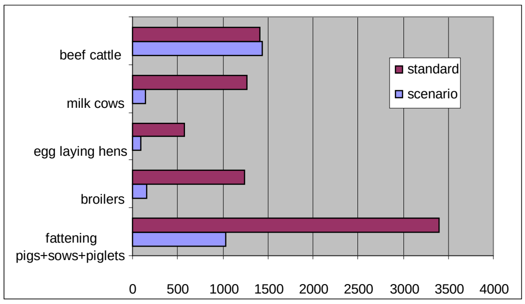


Figure 12 Use of grain (left) and soybean (right) (in kilotons) in quarter 8 after a stop on soybean imports, combined with 25% reduction in yields of roughage, grains and soybean in years 0 and 1

Figure 12 shows the changes in use of feed. The beef sector adjusts its use of soybean feed only little, while pork, poultry and egg and milk sectors all reduce soybean use dramatically.

6.3 Trade and yield reduction shocks with more biofuel for 2020

The above scenarios are for shocks to what could be the situation in the EU by 2020 under standard assumptions on policy. These standard assumptions do not include a purposive policy of the EU to increase the acreage under bio-fuel crops in the EU. Yet, if such policy were implemented, much more protein would be available within the EU (for the seed of biofuel crops contains both oil *and* protein rich meal) and an import stop on soybean could be much less harmful for the protein provision of the EU livestock. For this reason, this paragraph looks at the repercussions that trade shocks and other calamities would have in a situation where the EU would grow its own biofuels.
The biofuel scenario sketches what might happen to the market for protein feed in case of stringent implementation of EU policy regarding the production of biofuel crops.
Present plans of the EU include the compulsory mixture of biofuel into the gasoline and diesel fuel by 2020 to the amount of 10%, and to reach 5.75% already by 2010. Market share in 2008 was 2.62%.[2]
Without restrictions on EU trade in biofuels, most of the extra biofuel requirements will be met by imports. This will raise world market prices, and divert agricultural land from food or feed crops to biofuel crops. Area consequences within the EU would be minor. Bindraban *et al*. (2008) indicate that with full liberalization of agricultural markets (including those for meat and dairy), and no restrictions on where the biofuel crops should be grown, the EU area for energy crops would take 8.8 M ha. For comparison, the 2005 area in the EU for soybean, sunflower, rapeseed and pulses amounted to 9.4 M ha. The demand for land in the EU as a consequence of biofuel requirement will therefore be negligible under this assumption of full tradability of biofuels.
With restrictions on where the biofuel crops are grown, more impact on EU land use is to be expected. Bindraban *et al*. (2008) elaborate a case in which 57% of the biofuel must come from EU sources. This would claim 13.9 M ha in the EU consisting of 8.5 M ha of oilseeds (rapeseed and sunflower) for bio-diesel and 5.4 M ha of grains and sugar beets for ethanol production. They further comment that by 2020 some 26 M ha of agricultural land can be expected to be taken out of production compared with 2005, due to regular abandonment of farmland. This should enable these crops to be grown without necessarily crowding out of other food and feed crops.

We take the rather extreme case that *all* biofuel crops must be grown within the EU. Bindraban *et al*. (2008) calculate that in this scenario some 24.4 M ha must be grown for biofuel purposes, including 6.3 M ha grain, 3.1 M ha sugar beets, and 15 M ha oilseeds. If no additional land would be taken into cultivation, this implies that the area for food and feed grain production diminishes by at least 6.3 M

[2] http://www.plateforme-biocarburants.ch/en/infos/eu-results.php

ha and that the area under oilseeds increases from 9.4 to 15 M ha, or by 6.6 M ha, which may also come at the cost of grain area. The other side of the coin is that the oilseed production from this 15 M ha produces – in addition to the oil – 21 M tons of soybean meal (sbm) equivalents (ibidem, p 47). This may replace imports of soybean (meal). In addition, the processing of the grain for ethanol production yields as a by-product DDGS (Distillers dried grain soluble) which would provide another 8.8 M tons of sbm-equivalents.

The additional 29.8 M tons of sbm equivalents would be equivalent to an area of soybean equivalents of 13.4 M ha (with a yield of 2.2 tons of sbm per ha in 2020).
For the simulation of this case, we could depart therefore from the following changed conditions:
Basic grain area: minus 6.3 M ha
Basic 'soybean' area: plus 13.4 M ha

The original area under oilseed crops (of 9.4 M ha) remains cultivated and can be left out of these calculations. The same holds for sugar beet area. But the use of DDGS requires further consideration: if we subtract grain area (as the grain is no longer available for feed) and add the sbm equivalent of DDGS to the 'soybean' area, we do as if the area required to produce the 8.8 M ton of sbm eq in the form of DDGS would be 4 M ha (=8.8/2.2). But it took actually 6.3 M ha (of grain). Similarly, to produce the other 21 M tons of sbm eq in the form of rapeseed and sunflower requires 15 M ha, rather than the calculated 9.4 (= 13.4 – 4).
To accommodate for this change in source of proteins, from soybean to less protein-rich crops, we diminish the assumed yields of 'soybean' area from 2.2 t/ha to 1.4 t/ha. With this yield, the sbm eq of 29.8 M ton requires 21 M ha.
The original area of soybean will, in this scenario, no longer is grown, as it would be more attractive to grow the (other) biofuel crops that yield more oil, while still yielding the by-product of sbm equivalents.

A final consideration is the price. In the biofuel studies, these crops fetch higher prices. Only then will farmers be willing to grow the crops. The higher prices are induced by the demand for the oil, and not by demand for the meal. Actually, in a free trade world, more biofuel production may lead to lower meal prices. This is not included in the model, however, as the relevant scenario (calamity) is the one in which no trade is possible for some years.

Summarizing, the biofuel scenario is implemented in the model by assuming

- grain area to be lower by 6.3 M ha,
- 'soybean' area to be higher, 21 M ha, but
- yields of sbm to be 1.4 t/ha rather than 2.2 t/ha.

Obviously, this would all be of no consequence for the simulations under the assumption of open borders. The scenario is only relevant when combined with no-trade calamities.

Simulations

By assumption in the Biofuel scenarios, the EU produces much more oil seed crops and, with the assumptions made above, it is hardly importing proteins anymore. Instead of importing some 25 M tons of feed per year, these imports would dwindle to a mere 2 M ton or thereabout in soybean equivalents. This has implications for the stockholders too. In the traditional conditions, they would be storing what is usually imported for a quarter, hence stock levels close to 7,000 kton. In the new conditions, with a production in the third quarter of every year of around 28 M tons, they must store this much, at least for some time. In line with the assumptions for the grain market and the reality as observed for the USA, they are modelled to release the stock only gradually over the year, in each quarter they release a quarter of the stock level above the minimum quantity of 4,000 kt. Therefore, the general price level of sbm in the EU will be marginally lower than in the previous simulations.

The new situation in which the EU produces much biofuel itself impacts on its resilience to trade shocks. We make the following simulations for this case. We start with a trade stop for soybean. This is likely to have mild effects on the animal production, compared with the case above when the EU produced only little protein feed. The next simulation is for an import stop of soybean, combined with a two-year yield reduction of 25% in protein crops, grains and roughage. While the reduced production of grains has no effect, as this can be imported freely, the reduced production of roughage will affect the dairy sector immediately.

Scenario 6: No trade in soybean (meal), with more biofuel

Assumptions: no imports of soybean, free trade in grains, with more biofuel

We simulate the situation of no trade in soybean (meal), starting in the first quarter of year 0. The stockholders actually have not much reason to change their policy. A crop in the order of size of 90% of usual demand is expected to be produced in two quarters time, and what is in stock equals normal demand for three quarters. Holding on to a minimum stock level of 4000 (equal to annual imports) seems a reasonable policy. Higher prices will 'automatically' result from stocks running lower than normal. Charging high prices at the onset of the trade ban would leave stockholders with larger amounts of soybean for later quarters, and also trigger higher levels of production. Prices result from comparing the standard released quantity (stocks above the minimum, divided by the number of months to go before harvest) to the normal demand and using an elasticity of 0.4 to tentatively set the price that equates the two. When stocks go down, prices go up, and supply (in the third quarter) responds. With the sizeable share of land devoted to oil seeds, the soybean area elasticity is somewhat smaller (around 0.7) than when the area was much smaller.

This release of sbm will cause sbm prices to go up, initially to 1.5. Grain prices will remain the same, as grain trade is still possible. Product prices will rise, but by no more than 15% (Figure 13). The higher prices will depress demand by about 4 percent. Supply of sbm rises from 30 to 35 million tonnes in the first year. This will push prices back to the original levels by the end of the second year. The reduced grain production (- 20 million tonnes) is compensated by reduced exports. The SBM market can therefore, rather easily deal with the trade block in this situation.

For animal production, this scenario works out rather mild: egg prices go up by 15% following the higher sbm prices, fall below par in the third year and return with some oscillation to the original levels in a few years' time.
Comparing Figure 13 with Figure 6 shows that the effects of a trade embargo of soybean are far less in the biofuel scenario, where the EU grows its own protein crops.

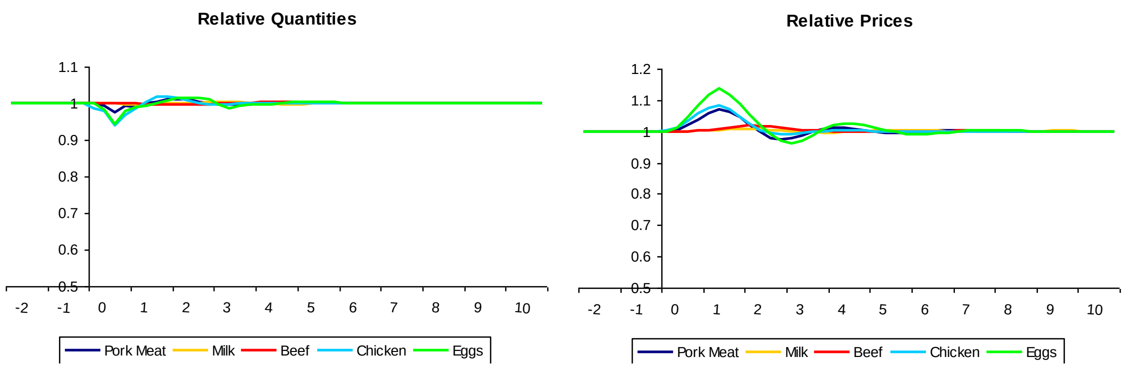


Figure 13 Responses to a stop on soybean imports in years 0 and 1, with more biofuel. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

Scenario 7: Yield reduction without trade in soy, with more biofuel

Assumptions: Effective roughage availability and yields of grains and protein crops fall by 25% in years 0 and 1, free trade in grains, with more biofuel

Combining the trade disruption with a yield reduction in the EU will change these conditions. The simulation is for a reduction of yields of grains, oil seed crops and roughage by 25%, with effects on prices of soybean and roughage. Grain is assumed to be traded freely and its price equals the world market price.

A very severe shortage of roughage will result for the middle of the period, which is during the winter after the first year of yield reduction. Shortage is so severe that more cows are culled than otherwise would be the case and herd size will be reduced by 30%. This will result in less milk production as of midyear 1 (-40%) leading to higher milk prices (+70%). Young stock will remain to be reared however, so that the yield reduction will not have a long lasting impact: by year 5 production and prices will have come back to their original levels. It is mainly the roughage shortage that plays a role here. As many cows can no longer be fed, they are culled. Initially the meat supply will increase (in the quarter after the acute roughage shortage, meat supply goes up by 42%). Thereafter the beef sector will suffer from lack of supply of young stock and decreased investments given the lower product prices and higher feed prices. The ensuing shortage of beef supply will push up prices to a maximum of 65%. By year 5 normal levels are reached again.

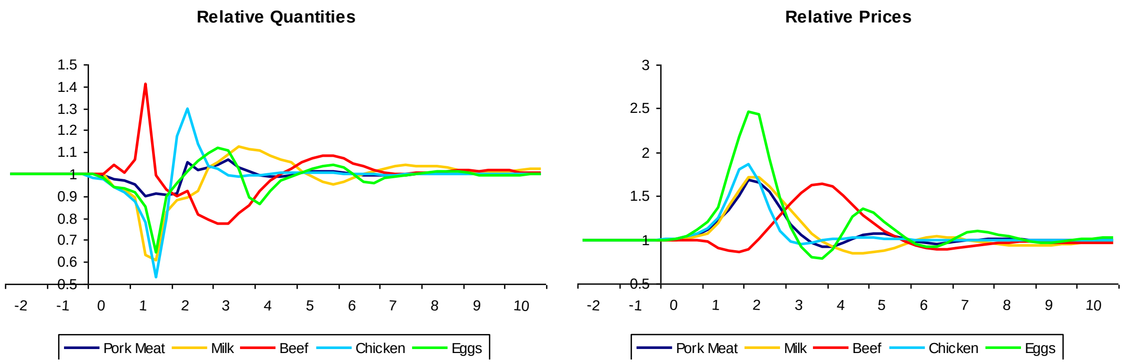


Figure 14 Responses to a trade embargo combined with yield reduction in years 0 and 1, with more biofuel. Year after start of calamity on X-axis, Relative quantities and prices on Y-axis.

In the simulation of scenario 7, shortages of sbm will become acute in the second year. During the first year prices go up mildly, but the disappointing harvest after the import stop reduces supply before the second harvest to such low levels that prices shoot up (to a maximum of 2.8). Pork production is affected: prices go up to 1.5 in quarter 4 of year 1. For eggs and poultry, the effects are even stronger. Comparing Figure 14 with Figure 11, we see that the pork sector is quite less affected by this scenario than in the case of no biofuel crops.

Conclusion on the biofuel scenario

The case of biofuel production in the EU implies more domestic production of biofuel crops, by assumption. This helps the feed sector in providing much more domestically produced protein feed. Only little import would be required if all crops are grown to fulfil the requirement of 10% biofuel in 2020. Therefore, trade disruption can be more easily dealt with. Stocks are normally higher (as a larger annual production must be kept in store), and the resilience to trade disruptions is stronger too. Yield shocks on the other hand can be more dramatic.

Figure 15 shows the effects of the two important scenarios (of no soybean imports, combined or not with low yields) for the three most sensitive sectors egg, pork and poultry production. The graphs show the relative maxima and minima of prices and production, taken as a ratio with respect to the base scenario. As shown in the three graphs on the left, the import stop on soybean causes much stronger price and production movements when no large EU production of biofuels is undertaken: the S-bars are typically longer than the B-bars. Measured by difference between maximum and minimum prices, growing biofuels reduces sensitivity from 67 to 18 percent for egg prices, 87 to 10 percent for pork prices, and 106 to 9% for poultry prices.

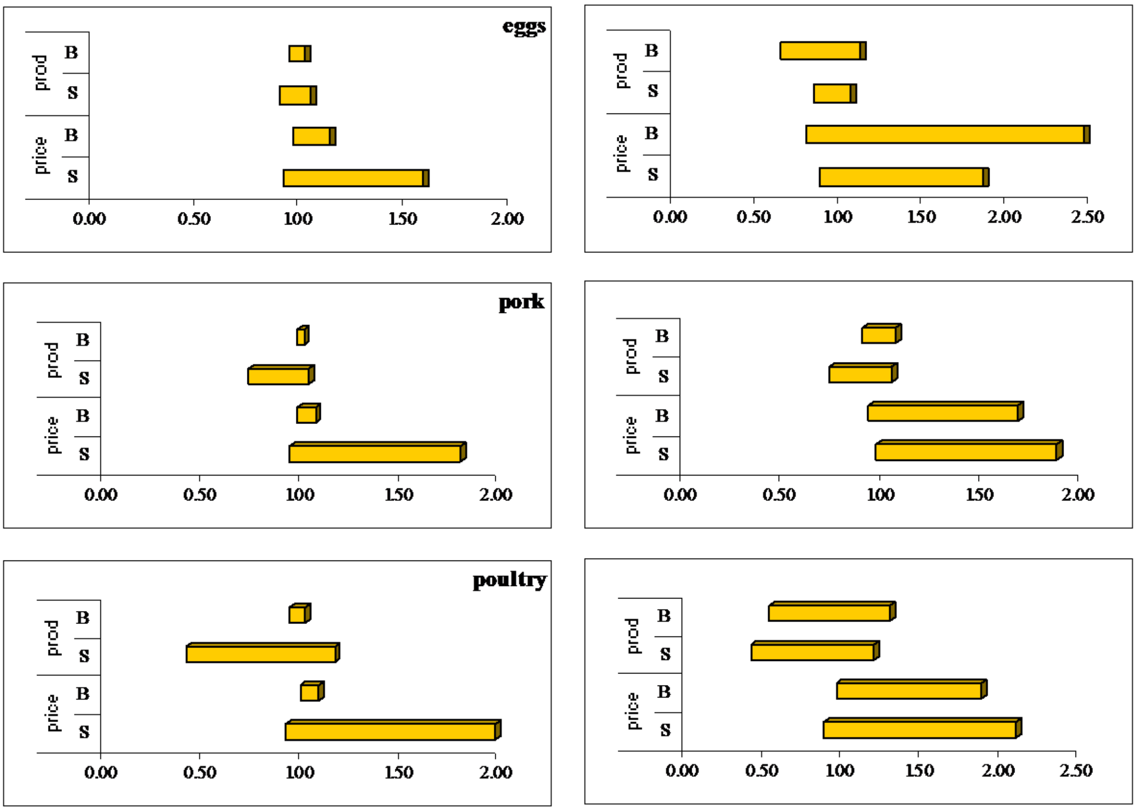


Figure 15 Ranges for production and prices for eggs, pork and poultry (top, middle, bottom), relative to base scenarios, with (B) and without (S) large-scale biofuel production in the EU. Left: no soybean imports, right: no soybean imports and 25% lower EU-yields

On the right hand side, the three graphs show the ranges resulting from no soybean imports, now combined with a 25% yield reduction. While the S-bars are not that much affected by the additional assumption of low yields, the B-bars are now much longer, showing the sensitivity of prices to domestic yield shocks in the biofuel case. As a result, egg production and prices has now become more sensitive to shocks under the biofuel case than in the no-biofuel case. For pork and poultry, growing biofuels in the EU still means less sensitivity to trade+yield shocks. Measured again by difference between maximum and minimum prices, growing biofuels increases sensitivity from 98 to 167 percent for egg prices, and decrease it from 91 to 75 percent for pork prices, and 121 to 91% for poultry prices.

Overall, an EU with domestic production of protein feed shows higher levels of resilience to trade shocks. Its resilience as to multiple shocks (here represented by trade+yield shock) is still higher when looking at the pork and poultry sectors, while lower in the egg production sector.
In the no-biofuel case, the added yield shock increases price swings by 31, 4 and 15 percentage points for the three sectors egg, pork and poultry. In the biofuel case, the additional effects on the price amplitude is 149, 66 and 82 percentage points, showing the increased sensitivity to domestic climatic disturbances within the EU.

6.4 Animal diseases

'*The blight in the beef market caused by BSE may pale in comparison to the potential damage to world chicken supplies that may be caused by avian influenza. One disease after the other becomes a focus of preoccupation and potential market disruption. ... Considering the rapidity with which either disease spreads, by animal transport or migratory vectors, veterinary pandemics are likely to occur with increasing frequency. This eventuality is impossible to predict in its exact nature, but the effects within the agricultural economy are possible to model.*' (Nowacki *et al*., 2007)

Assumptions: diseases strongly reduce animal production (directly through dying of affected animals and indirectly through active culling); availability of animal products from outside EU is very limited, due to import stop and/or lack of capacity of world market to compensate for the drop in production in EU.

Outbreaks of infectious animal diseases (epizootics) can be virulent and affect large parts of animal populations at the regional level. Especially when these diseases also infect humans (zoonoses) or provoke in trade barriers, control measures generally resort to massive culling and destruction of infected animals and also of (possibly not yet infected) animals around known infected farms/areas. Even when vaccines against these diseases exist, culling may still take place on a large scale instead of using the vaccines preventively, if their use may result in strong private or public trade restrictions (e.g. Berentsen *et al*., 1992). This may especially be the case if the vaccine does not have a marker to distinguish vaccinated from infected animals in tests.

The model is used to estimate the effects of a hypothetical infectious disease that equally affects the three types of animals in the model: cattle, pigs and chicken, and all over Europe, without the possibility to use a vaccine. This disease may be completely new or mutated from an existing disease. Alternatively, various different specific diseases equally affect the three kinds of livestock. Whether this is feasible or not, and what characteristics this disease would (need to) have are not questions to be answered by this study where we simply evaluate the 'what if such disease situation occurs' question. We evaluated three levels of severity of the disease situation, expressed in three mortality rates (from disease plus culling) of the whole animal population: 1%, 5% and 10% mortality per quarter, and we assumed that this disease has this effect for two consecutive years (0 and 1). This mortality includes

1. the animals that die after having been infected (either naturally or by active culling)
2. the possibly infected animals on farms around infected farms that are preventively culled
3. animals culled to overcome overpopulation in farms that are affected by a prohibition to transport live animals (so-called 'welfare culling').

Before evaluating the results, we emphasise that the model does not take into account the response of consumers other than through effects of changes in prices, though it is clear from experiences that epidemics of animal diseases will reduce at least temporarily the consumption of meat from affected livestock.

In addition, the model in fact assumes agricultural production to take place in one big virtual farm that covers the whole EU. This farm has no financial limitations, and it cannot go out of business, e.g. due to bankruptcy (as may happen to individual producers). It can therefore react continuously and instantaneously to market conditions, such that recovery of production capacity can be swift and is not affected by delays related to the time it takes to build up new production capacity to replace vanished capacity. This is particularly so, because setting up of starter animals is not prohibited in the model, while in reality this could be an explicit policy measure to prevent the disease to maintain itself in a region or the result of (temporary) prohibition of transport of life animals. In fact, the model will calculate a higher number of starters when prices of products increase due to lower production. For this reason, model results may underestimate effects of diseases on production and prices.

Finally, effects of animal diseases on availability and prices of animal products depend on the possibility to import these products from outside Europe. If import is unrestricted, prices and availability will be affected by additional transport costs, and the higher world market price due to a lower global availability. However, the model does not include this type of interaction between EU and world markets and it cannot calculate these effects. For the purpose of this study, this is not such a big issue, because in a fully open market, import of animal products into EU may counteract the reduction of animal production in the EU caused by the diseases, albeit at higher prices. This may create shortages and higher prices of animal products in other parts of the world, but that is beyond the scope of this study.

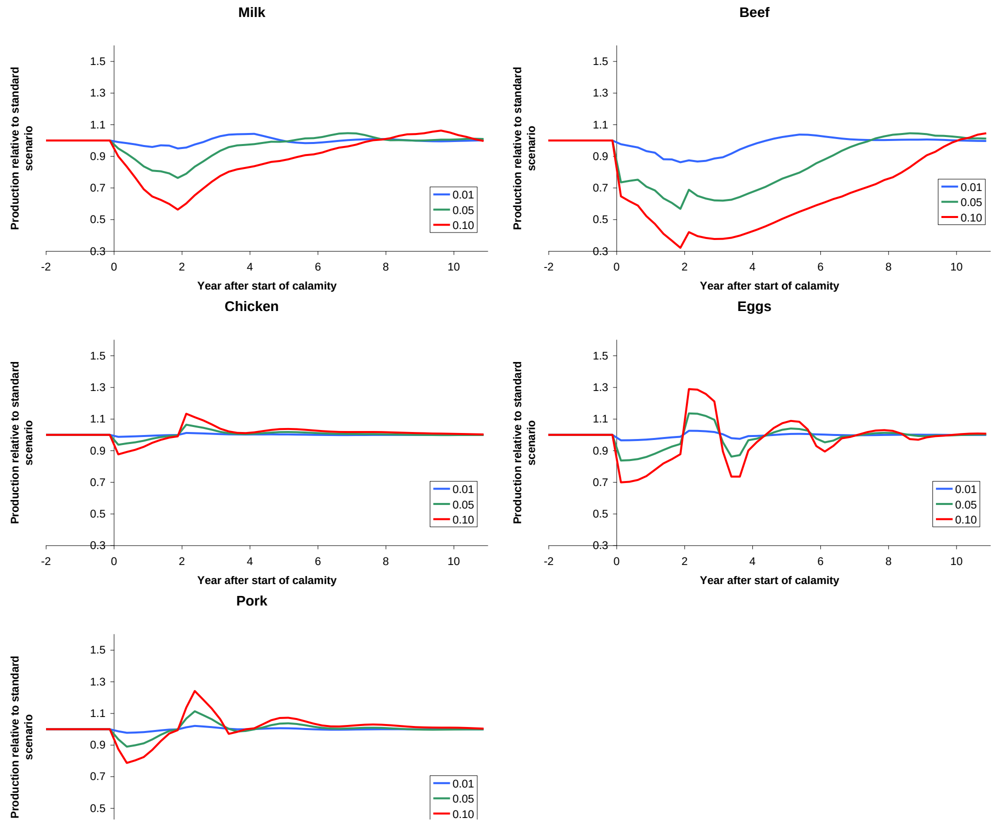


Figure 16 Effects of different severity levels of disease (mortality in fraction of living animals per 3 months) on production of milk (top left), beef (top right), poultry meat (middle left), eggs (middle right) and pork (bottom left). Production is given as a fraction of production level under the standard scenario.

On the other hand, because the model assumes the disease(s) to be everywhere, there is no compensation for lost productivity in affected areas by increased production in disease-free regions. For diseases that spread slowly, this may result in an overestimation of the effects of the disease.

Quantification of the importance and relevance of these potential under- or overestimation of effects cannot be done on the basis of this model.

Only if import of animal products is restricted, may animal diseases cause severe shortages and high prices of such products. Such import restriction could be part of the strategy to fight the disease being a measure to prevent further import of the same or other diseases. The scenarios in this section therefore assume the extreme situation that import of animal products is effectively not feasible during the period that diseases are active.

Outcomes
As expected, production in all animals systems drops after initiation of the infection (Figure 16). Where milk and beef production only start to recover after the infection has stopped (end year 1), the other animal production systems have their lowest production already in the 2nd (poultry) or 3rd (pork) quarter of year 0. These systems respond faster to increasing prices (Figure 17) that result from the lower production, because of the much higher number of offspring per female animal per year compared to the single calf that a cow can produce per year. The dairy system recovers slowly because of its low reproduction rate, with cow calves comprising only about 50% of total calves produced, and because it takes these calves minimally about 9 months to start lactating. The beef sector has an even slower recovery, because less calves become available from the dairy system, where also less of the underperforming (older) animals are selectively removed than under normal conditions.

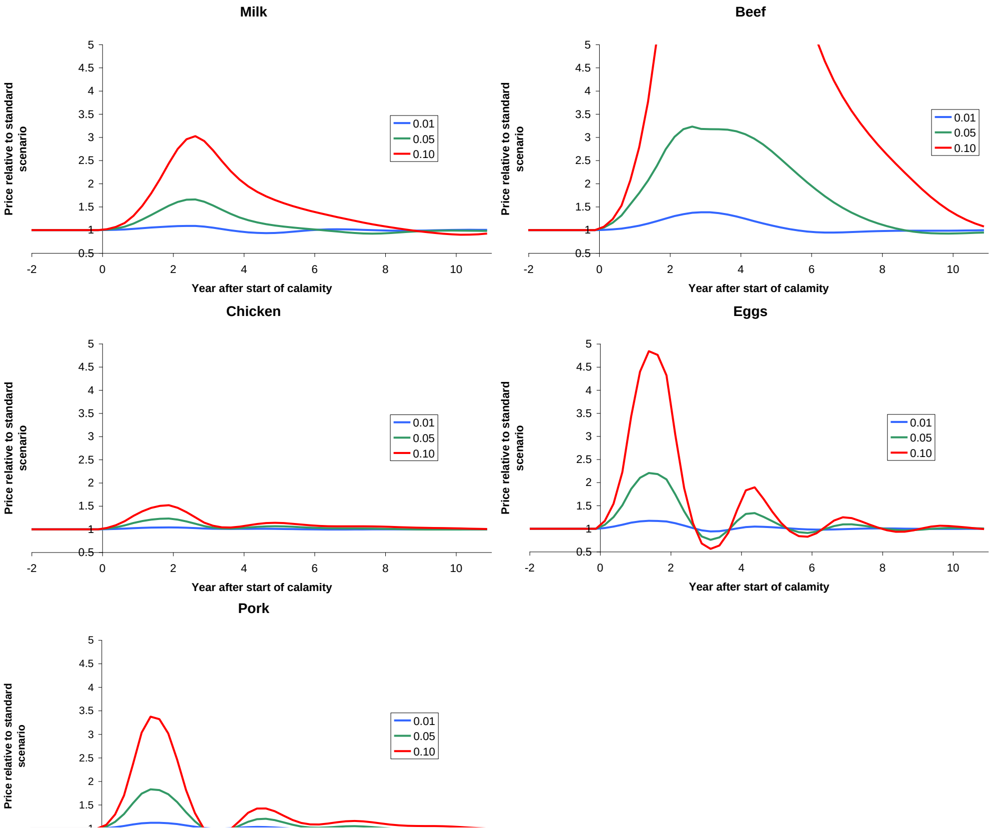


Figure 17 As Figure 16 for prices of products.

The mortality rate has for all production systems an expected negative relation with the lowest production per quarter during the epidemic and an equally expected positive relation with the highest relative price in that period (Figure 18). Especially if even higher mortality rates are included (such as 25% per quarter), these relations become strongly non-linear, which implies that it will not be easy to derive simple rules of thumb to predict possible effects of diseases.

Conclusions

Particularly the dairy and beef production systems may show strong reactions in production, price of produce and time needed for full recovery when hit by an epidemic. The other animal production systems also show strong reactions, but over a much shorter period as they show fast recovery. Due to overcompensation, some cyclic ups and downs in production and (inversely) of prices show up, but whether this puts a lot of strain on the stability of the sectors is doubtful.

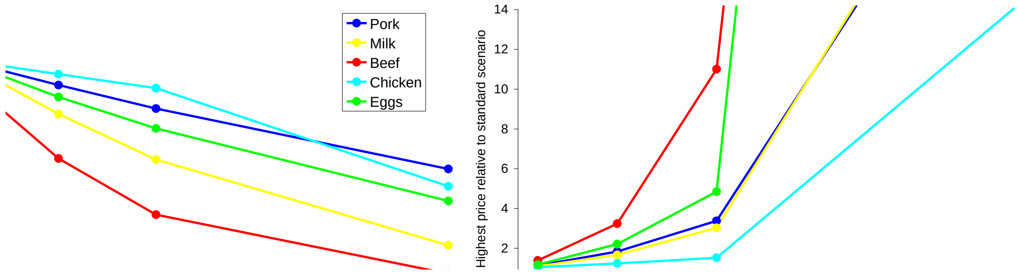


Figure 18 Effect of mortality rate on the lowest production (left) and highest price (right) in a quarter, after initiation of the epidemic for the various animal production systems

Even at 25% mortality per quarter (which seems a rather absurd high rate to occur EU wide[3]) over a period of 2 years in all of EU (which is rather long compared to known epidemics of classical swine fever), total meat production in the worst quarter is at most reduced by about 60% (Figure 19). To a large extent, this is related to the limited reduction in production and a fast recovery thereof in the pork, chicken and egg production systems.

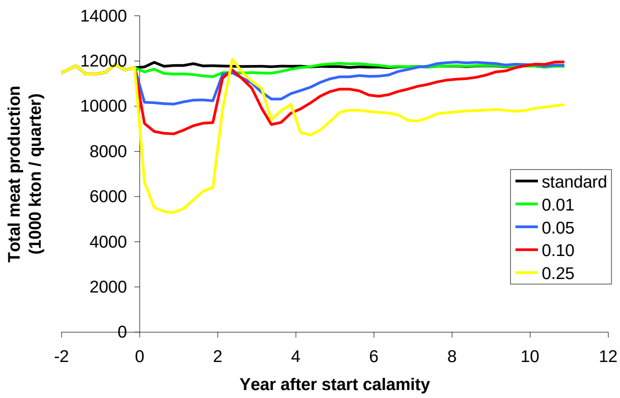


Figure 19 Total meat production (beef + pork + chicken) as affected by mortality rate (indicated by the values in the headers)

A production of 4200 million kg meat in the quarter with the lowest production (mortality due to disease at 25% per quarter; Figure 19), and a population of 496.4 million in 2020, results in an average daily meat availability of (4200/90)/496.4 = 0.094 kg meat per person per day in that quarter. This is slightly below the advised amount averaged over adults and children by the Dutch Food Centre (a

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3 For reference: in the Netherlands, about 9.7 million pigs out of a total population of about 20 million were culled between February and September 1997 during an epidemic of classical swine fever. This roughly translates to about 20% mortality per quarter. Only about 650 thousand culled animals came from infected farms, about 1 million from neighboring farms (preventive culling) and about 8 million (welfare culling) from overpopulated stables due to a prohibition regarding transport of living pigs. http://www.volkskrant.nl/binnenland/article173552.ece/Test_voorkomt_massaal_ruimen_varkens

daily meat ration for adults of 0.100-0.125 kg and for children of 0.080-0.100 kg; www.voedingscentrum.nl/nl/acties-achtergronden/schijf-van-vijf.aspx).

Therefore, availability of protein from animal production may be affected, but not easily be reduced to levels that are below minimum requirements to sustain on average sufficiently high protein content in the diet of EU citizens. However, although in this worst case scenario total meat production may still be sufficient to cover the minimal meat demand per individual within the EU, this does not imply that indeed everybody will have access to sufficient sources of meat-protein. It seems realistic to assume that especially poorer people will have less access than the average EU citizen to such protein sources (see also section 7.4), which may lead to malnutrition in these groups. However, this study is not geared to give a reliable quantification of the number of people possibly affected.

7 General discussion and conclusions

7.1 Model approach

The analysis of the results of the model simulations helped clarify the impact that shocks may have on the EU animal production sector. In scenarios with and without biofuel crops being grown, we simulated the impacts of trade embargoes and yield reductions. The simulations make clear that yield reductions are particularly important for the dairy and beef sectors, while embargoes on trade in protein crops would affect the pig, poultry and egg sectors, unless these crops are grown at a large scale within EU's borders.
The yield reduction in roughage is simulated in its strictest sense: a clear lack of roughage available to feed the cows. In practice, such a severe shortage is unlikely to result from a mere drought, as access to natural sources of roughage, like grass from nature reserves, may to some extent substitute for pasture-grown grass (even though grass production will be reduced in those reserves as well). While the costs of roughage would go up (and quality could go down), the shortage may not necessarily lead to culling of cows at large scale. Alternatively, we can think of the simulations as depicting what might occur if roughage became scarce not (only) because of a physical reduction of production, but also because of roughage becoming unfit for animal consumption, e.g. due to nuclear or other contamination.

There are various reasons why our model may lead to an over- or underestimation of the effects of calamities; major factors are:

- **Single big farm approach in the model**
  We simulated the responses of agriculture to calamities as if there is only one representative farm all over Europe, with the same decision making everywhere, and with an unlimited capacity to recover from any physical or financial shock. In reality, individual farms may show a more variable response to financial and physical shocks, possibly resulting in a different total effect of a calamity when compared to the big farm model approach. The different decision making of individual farms, may lead to part of them to collapse without being able to recover. Surviving farms then will have more room for expansion, partially helped by the then prevailing higher prices for the products. Eventually, however, it is unlikely that full recovery will be achieved within a few years. Therefore, the simulations are more optimistic than the actual world is likely to be, especially regarding the medium term effects of calamities. In principle, the model could be made more sensitive to risks for individual farms, by incorporating different farm types according to type, scale and intensity of production. Adding type specific risks of going out of business (as fraction of the total production within that farm type) in relation to the ratio of prices of products and inputs could be used to better mimic boom and bust cycles for the different farm types. While this would require a major effort in model formulation and data gathering, which was beyond the available budget, it is doubtful whether this approach would provide drastically different results for the short-term effects of calamities: most farms that go out of business will do so only after a calamity has affected production or imports. Effects on longer term may however be more pronounced.
- **Europe as a single, perfect market of goods and services**
  In our approach, we assume in fact that production and consumption of the different agricultural products is evenly spread over Europe, that a calamity has the same effects everywhere in Europe, and that transport of goods is never limiting the use of agricultural products for food and feed. In reality, however, Europe has some regionalization of production, e.g. for dairy products and a calamity may not have the same effects everywhere. Transport of goods may be hampered, either by a calamity or by policy decisions in countries to make agricultural products available with preference to certain

groups within Europe (e.g. citizens of its own country). Effects of a calamity then will be differentiated over Europe, which may lead to effects in some production sectors to be (much?) more pronounced than indicated by the model, both at national/regional level as well as at the European level. The current model could be adapted by separating Europe in regions or countries, each with its own setting of agricultural production and consumption. This could give a more realistic estimate of the regionalisation of the effect of a calamity and give the option to evaluate the effects of calamities with a regional impact only.

- **Farm decision making: use of relative prices vs. financial margins**
  In the current model, decision making on whether to in- or divest in agricultural production depends fully on (the ratio of) relative prices of products and inputs. This assumption may be adequate to estimate longer-term economic effects of prices, but in situations with strongly fluctuating prices, it does not allow to determine whether farms will generate enough income to be able to sustain their businesses and/or whether they had better shifted to production of other agricultural products. Especially for the period after calamities, modelling the margins of farms may generate a more realistic (and possibly bleaker) effect of calamities. Such 'margin modelling' would not be feasible with the big farm concept used in our model, but warrant an approach with farm types (see also discussion about the single big farm approach above).
- **Limited import of dairy and meat products**
  Currently, the EU is self-sufficient in the production of most animal products (e.g. Table 7). To quite some extent, this is achieved by subsidizing EU farmers at a rate of € 60 billion in 2009 from EU budget only (AFP, 2010) and not counting country specific subsidies, to keep them competitive in the world market. In addition, the EU regulates imports of meat through veterinary control measures (EU Directorate General for Health and Consumers, 2010). Similar health related conditions apply to the import of milk and milk products (http://ec.europa.eu/food/animal/animalproducts/milk/index_en.htm), while also additional regulations on animal welfare may become important (Stones, 2010). Current lack of compliance with these regulations by (potentially) exporting countries such as Brazil, Argentina and USA resulted in a rather limited import of meat (specifically beef) into the EU. However, in the future, exporting countries may comply better to these regulations, while also the competitiveness of EU producers may become less (e.g. as Evans (2008) indicates for poultry). The latter may be the result from increasing costs of production, but also to a reduction of financial support to EU farmers (which is heatedly debated in the political arena of the EU, e.g. AFP, 2010). This may result in imports of meat becoming more important than currently is the case and as is assumed in the model. The EU would then become less then self-sufficient in the production of meat and dairy, and become less dependent on soybean imports but more on meat and milk imports.
  In our model we assume that the EU is completely self sufficient in meat and dairy production (while in reality being a net exporter in most animal products), especially regarding the price formation within the EU. All changes in production level compared to consumptive demand are reflected in the modelled prices of the products. If we would include trade, most volume changes would not have a direct effect on prices, but merely result in a change in netto export. In fact in the effects on prices calculated in our model therefore overestimate the real situation. For dairy, where the EU is a rather big player on the world market (>30% share of trade), changes in export volume would logically lead to changes in the world market price. In fact, we have included that relation as a consequence of the zero-trade or closed borders, albeit a bit extreme. On the other hand, the modelled increases in prices due to reductions in production lead to faster recovery in production (and therefore again in recovery of prices to former levels) than would be the case if only costs of production would change, but not the prices of products.
- **Use of products from animal origin in animal feed**

Before the BSE[4] crisis, use of animal products in animal feed was quite normal in Europe. From 1996 onwards, restrictions on this use were imposed (e.g. http://ec.europa.eu/food/fs/bse/bse28_en.html), in effect, requiring animal feed to contain relatively more soybean than before. Better traceability of source, and quality of the contents in animal feed could make it possible to withdraw some of these restrictions. This could reduce the need for protein from plants and as such make the animal production sector in the EU less dependent on import or from domestic production of soybean or equivalents. The current study does not take into consideration this use of animal protein in feed, and as such may overestimate effects of a reduced availability of soybean (equivalents).

- **Elasticities of consumption and production**
  While the model assumes that demand elasticities in the feed market rise with higher prices, such an assumption is not made for the consumer demand. The base run of the model uses elasticities for meat demand from the Food and Agricultural Policy Research Institute (FAPRI) as in Table 17. The own-price elasticity of, particularly, pork is rather low, implying that a given supply shock leads to high prices.

Table 17 Base and alternative values for meat demand elasticities

	Price of beef		Price of pork		Price of poultry	
	Base	Alternative	Base	Alternative	Base	Alternative
Beef	-0.40	-1.44	0.10	0.97	0.01	0.10
Pork	0.03	0.32	-0.13	-0.79	0.01	0.07
Poultry	0.02	0.13	0.06	0.00	-0.31	-0.84

These elasticities led to the outcomes as shown in the Figures of Chapter 6. How the elasticities affect the outcomes for product prices is simulated by taking another set of elasticities, namely those applied to Germany in the CAPSIM model that simulates (normal) evolutions of EU agriculture (Witzke and Zintl, 2005:166). The values of the elasticities are as in Table 17 in the 'alternative' columns and include stronger own-price elasticities in particular.

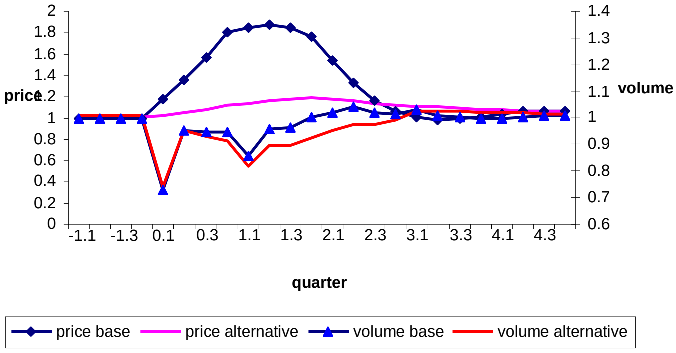


Figure 20 Comparison of prices and volumes of pork in two sets of price elasticities (base and alternative as in Table 17). X-axis shows the quarter after the start of calamity (in unit year.quarter)

After new calibration of the model for a base run, and new simulations, prices are generated for the various scenarios. We compare the prices resulting from the rather extreme scenario where soybean imports are not possible, and domestic yields of roughage and feed crops are reduced by 25%. Figure 20 shows the outcomes for pork prices for the two sets of elasticities.

[4] Bovine Spongiform Encephalopathy, commonly known as Mad Cow Disease.

As shown, the simulated price increase is reduced from more than 80% to less than 20%, due to the stronger elasticties. However, volume changes are quite similar with peak downward changes of 26% in both simulations, followed by another peak 4 quarters later of 15%, and 18% respectively for the base and the alternative scenario.

Stronger volume responses could be generated in a model with stronger elasticities with respect to pork-feed price ratios. If setting up young piglets would respond to the pork-feed price ratio with an elasticity of 0.4, rather than the present value of 0.2 taken from FAPRI (and using the high pork demand elasticities as we did above), pork quantities would fall to -30% in quarter 1.1 (compared with -18%), while pork prices would rise again to 2. The initial responses in the first year would be quite similar however.

7.2 Speculation and exploitation

In the scenarios with import stops on soybean (and grain), the EU will have to make do with whatever stock there was in the region before the embargo struck. The owners of the stock will be in a position to ask almost any price for their feed. What are reasonable assumptions about their behaviour in these conditions?
Note that the behaviour of the stockholders in normal times is to carry stocks just for smoothing transactions. Speculative motives in normal times are not considered here, as they are bound to be negligible compared to what happens in case of calamities.
In case of a sudden stop in supply to these stockholders, they change their behaviour. Prices are no longer given by the world market, but determined within the EU. In addition, stockholders can no longer just pass on the feed to their customers, as this would soon exhaust their stock.
If stocks were held by a single firm, this firm will try to maximize its profits from selling the stock and it will consider that by supplying less, prices will go up. There are three forces that put restrictions on the extent to which supply is withheld. One is that higher prices in the present quarter lead to ever-lower demand now and later. If demand would hardly respond, prices can be set very high. In our case, demand becomes more and more responsive when prices go up. In addition, the supplier must take into account that higher prices in year 1 will trigger more production in year 2, which also erodes the possibilities for monopolistic profits. This by itself would not be sufficient reason for restraint by the monopolist. But then, another force has to be considered: the value of his remaining stock. Unlike the case of a standard monopolist, this stockholder looses the value of his stock if it is not sold! The stockholder has a clear incentive to sell the stock within the period during which trade is curtailed. This timing is also affected by the harvest that is realized in Q3.

The third force is uncertainty about the duration of the import stop. This reinforces the second point in that the stockholder has an incentive to sell (at the ruling high price) before the import stop ends.
In the process of the rise in prices, speculators (large and small) are likely to intervene. They can speculate on the future market conditions in the same way as sketched above for the stockholder himself, but they can also speculate on the short-term rise in prices, typically shortly after the import stop is in place. This latter type will reinforce the rise in prices, and may well lead to overshooting of any "equilibrium price" that would materialize in the absence of short-term speculation. There are some measures that a government may take to prevent such speculation, e.g. by prohibiting the selling of what is not yet owned, or by making speculation transactions more expensive, e.g. by demanding ownership of a minimum amount of physical products per transaction (relative to the total volume of the transaction).

The likely outcome of the process – if not disturbed too much by overshooting – is that a monopolist would spread his supply over the period as smoothly as possible, but with some preference for earlier selling months. The model is used to elaborate this in more detail. We focus on the returns to the holder of the original stock. Hence, we look at the revenues of selling this stock over the coming quarters, as a function of the price set in the first quarter. In the other quarters, prices are determined by the standard behaviour, which is that stockholders make an estimate of the price at which the remaining stock can be sold in more or less equal amounts until the next harvest. The question is if the stockholder would benefit from setting very high prices at the onset of the trade stop. We measure their profits by looking at their sales until Q7, i.e. until the crop of the second year enters the market (going beyond this until the end of the trade stop would render a loss for stockholders as expensively bought feed is then sold at world markets). We subtract the costs of buying the initial stocks and the first-year crop. No discounting is done, no storage costs are considered. Figure 21 shows that initially stockholders will do well in raising the price, from 1 to 2.65. Setting the price still higher is not attractive, as less is bought and more is produced.

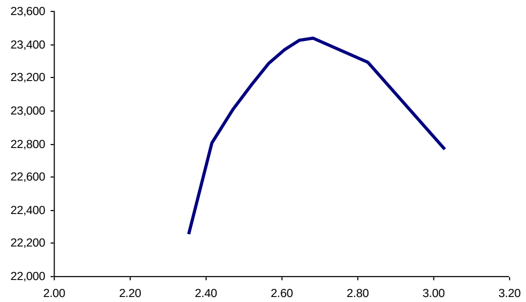


Figure 21 Profits of stockholders (Y-axis) by price set in Q1 after start of calamity (X-axis)

Of course, other strategies can be thought of, including setting a fixed price throughout the period. Any strategy strongly depends on the duration of the import stop: if it lasts only for 4 quarters, setting a very high price would certainly not be optimal, as much of the stock may remain unsold.

The standard as modelled in the base run is to assume an initial target setting by stockholders to sell more or less the same quantity in each quarter. That is, prices are set, such that – with the approximated demand elasticity of 0.4 (which normally applies to a price level of 1.5) – this amount could be sold. Actual sales can differ, and are reflected in higher or lower stock levels in the next quarter, when again a redistribution is made. This results in a level of profits over the original opening stocks that is only marginally different from the above "optimal" set-price strategy, with a profit of 22.9 compared to an optimum of 23.4. Prices now fluctuate more, between 2.55 and 2.98.

The same outcome results from the situation in which there are many stockholders, competing among themselves, and all knowing that aggregate supply is restricted. They will typically smooth the total supply so as to have more or less equal supply in every period. Nevertheless, herd-like behaviour may occur with all stockholders clinging to their stocks despite enormous price spikes. Further research on this could be useful.
Stockholders will not normally know how long the period is for which their aggregate stocks should last. They may well sell too much in the early quarters, expecting that the disruption will not last long, or that a good crop will soon be harvested. If these expectations are frustrated, by continued embargo, or by a drought, the region will find itself in an even more difficult situation.

Concluding, we can say that the model shows how sensitive the outcomes are to assumptions on how the actors involved will react. Rational stockholders, we argue, should smooth the supply over the quarters during which scarcity prevails. However, without knowledge about its length, even these rational actors are at a loss. Concerted action with governments, e.g. on communication to producers and consumers and in regulating use of stocks, may be helpful here, the more so if helped by regulation. As shown by Dutch legislation, the existing legal framework includes regulation against hoarding food and bringing stocks under government control[5].

[5] Hamsterwet, Noodwet voedselvoorziening, Coördinatiewet uitzonderingstoestanden.

The present simulations suggest tripling of prices is likely in the case of soybean import stop. It seems unlikely that speculation would lead to even higher prices than this, as it would only reduce demand any further – and even in the short term irreversibly so when cattle is culled and no young stock is set up. However, the stage is set for 'irrational' behaviour, as the duration will be unknown.

7.3 The role of minimum stock requirements

A possible measure that governments can impose, or that the private sector could decide to implement by itself, is a minimum level of stocks that must be kept in store during normal times. The higher this level, the larger the resilience will be as to possible shocks. One way to show the effects is to simulate what would happen in case imports of soybean are suddenly disrupted under three assumptions as to the normal minimum stock levels that are held.

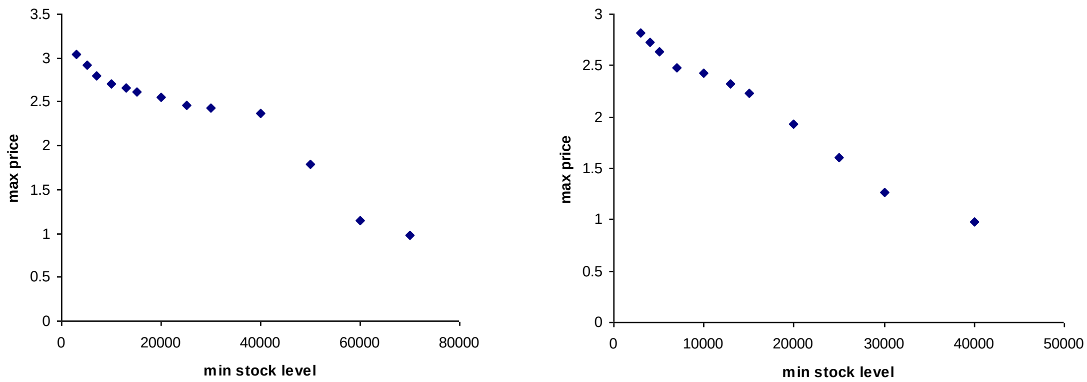


Figure 22 Maximum prices after soy-trade stop for various levels of minimum stocks of soybean; left: 2 years shortage, right: 1 year shortage

Higher levels of minimum stock requirements have a smoothing impact on the prices (Figure 22). Lower levels of minimum stocks imply that traders under normal conditions will keep smaller quantities of soybean in store. Once the imports are disrupted, this lower level of soybean available at the start of the crisis leads to higher prices required to squeeze demand to volumes that can be supplied for the next quarters. Note that during the crisis period, the model assumes that no minimum stocks requirements are taken into account.
However, the effects of larger minimum stock levels are not constant. The left graph shows the maximum prices that occur after an import stop, for different levels of minimum stock requirements. Quarterly consumption is around 8000 kt. We see a decline in the effect of additional stock between 20 and 40 thousand kt. This decline in effectiveness is caused by the influence that the first year has on the second: larger levels of stock imply lower prices in the first year, which leads to lower levels of production in that year. This contributes to later scarcity of soybean and puts some upward pressure on the prices. Only beyond 40 thousand kt, a further decline can be observed. At this point, the stocks are larger than what is required for 5 quarters' normal consumption. Combined with production this amount suffices to overcome shortages easily.
The right hand graph shows the same simulations for a one-year import ban. Here, an amount in store of at least 40 kt is clearly sufficient to prevent any price effect. This amount is sufficient to cover more than the duration of the shortage.

Economic considerations
Carrying large stocks entails costs for buying and storage. It brings benefits in terms of stability of prices and avoidance of extreme prices. The balance of costs and benefits depends on how this stability is valued.

Cost of storage critically depends on technology and the size of the facilities. Further research would be required to elaborate the details.
Benefits of stability are often expressed in a normative sense by referring to risk aversion on the side of the producer. This ‘aversion’, however, is for income risk, not price risk per se. While costs are fluctuating due to price shocks, so do revenues. With some delay, prices of the products respond to fluctuations in supply and therefore to fluctuations in feed prices. It is yet unclear, how this price volatility works out on profits and therefore on agricultural income. Volatility in the product prices will affect farm income more than that in input prices, as a result of substitution opportunities on the input side.
The variability of product prices will also affect consumers. As meat is a relative luxury (within food), stabilization of its price per se would bring only limited benefits for consumers.
The major benefit of reduced price variability might therefore lie in the avoidance of extreme prices. Extreme feed prices may have irreversible effects on some firms, such as bankruptcy, while other firms may survive because of their access to own or borrowed funds. The extent to which these considerations are relevant depends on the distribution of individual farms by the degree of their exposure: pig fatteners growing their own feed will not be affected by feed prices; large fatteners using purchased feed will be heavily exposed The EU network of farm data can provide a source, but further study is required to assess the extent of vulnerability of individual firms to price shocks.

7.4 Effects on consumers

The various simulations show that consumer will face (sometimes dramatically) higher prices of milk, meat and eggs in case of sudden disruptions in soybean trade and/or very serious yield reducing events. Therefore, their consumption of grain products will fall, assumingly with a rather small elasticity of -0.13. Similarly, consumption of animal products will fall too. However, consumer expenditure on these goods is likely to rise.

In 2008, average spending on food (not including catering services) in the EU as a whole and in the Netherlands was about 15 and 13 % respectively (Eurostat, 2008a). Within these expenditures, the cost related to consumption of animal products is important: some 25% of food expenditures are on meat and meat products, not counting the expenditures outside the house, or 3.6% of total household expenditures. The share of dairy products plus eggs in total food expenditures is around 14%, which equals 2.1% of total expenditures. In total, animal products comprise about 5.7% of total household expenditures.

The extreme scenario of trade embargo and yield reduction leads to (temporarily) higher prices for feed and food, except for grains. In the quarter with the highest prices for products, consumer expenditures on milk and beef rise by 50%, on pork by 120%, on poultry by 76% and on eggs by 25%. However, these changes do not occur simultaneously, and in some quarters, prices are (much) lower. Overall, therefore the expenditures of households on food may rise by at most 50% of their expenditures on meat, eggs and dairy, or by around 20% of total food expenditures, which equals less than 3% of total consumer budget.

Judging from these average data, we could assume that calamities hardly affect the consumer budgets. This may be true for the higher income countries, with good social security: in the Netherlands, expenditure on food as fraction of disposable income shows negligible differences between income categories. However, country specific data in the EU show that the fraction of expenditure on food (excluding catering services and alcoholic beverages) is strongly related to average GDP (Figure 23), with households in lower income countries spending up to 3 times more on food as fraction of their income than in the higher income countries. In addition, these country specific data show income levels to have a strong relation with expenditure on food plus non-alcoholic beverages, which are around 67% higher for households in the lowest income quintile than in the highest quintile (Eurostat, 2008a). In extreme cases, the lowest income quintile in low-income country Romania spends about 60% of its income on food plus non-alcoholic beverage, compared to about 7% by the highest income quintile in Luxembourg.

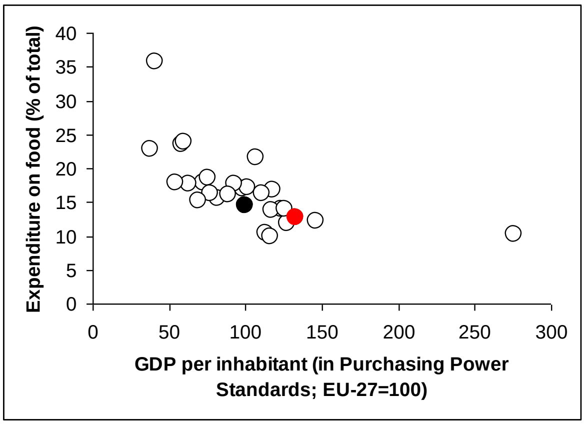


*Figure 23 Relation between GDP per inhabitant (in Purchasing Power Standard relative to EU average of 100) and average relative expenditure on food by households in 2007 in 27 EU countries. Black dot: EU average; red dot: NL data; open dots: other countries (*Eurostat, 2008a, 2008b*)*

The spending on meat, milk, cheese and eggs as a fraction of total spending on food shows no clear relation with GDP (Figure 24). Assuming that prices of these products relative to those of other food products are the same within the EU27, this would indicate that the fraction of meat, milk, cheese and eggs in the diet as such is independent of GDP in the EU 27.

It will not come as a surprise, that these findings indicate that drastic increases in prices of animal products may affect poorer people in poorer countries more than the richer people in rich countries, and most likely would require them to change their diet considerably by reducing consumption of animal products, or to buy cheaper, in general more fatty and unhealthy products. Under current economic conditions, lack of adapting the diet will force the poorest income quintile in Romania to increase their spending on food from 60 to about 70% of total disposable income. This seems rather impossible in view of the need to also buy clothing, pay rent or mortgage for housing, etcetera. Most likely, the reduction in amount (and quality) of animal products for the lower income groups may lead to a less healthy diet, with insufficient intake of protein and vitamins and higher intake of fat. However, this study cannot provide details on this issue.

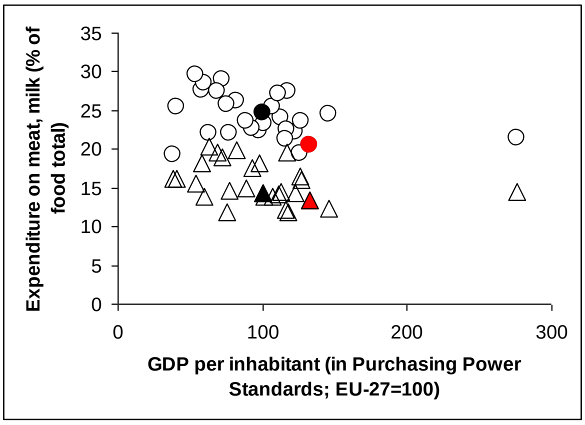


*Figure 24 Relation between GDP in EU 27 countries in 2007 and expenditure on meat (dots) and milk, cheese & eggs (triangles) relative to total spending on food and non-alcoholic beverages; Black symbols: EU average; red: NL data; open: other countries (*Eurostat, 2008a, 2008b*)*

8 Conclusions and Recommendations

This study focused on the possible effects of two types of potential calamities in the European food production:

- a (strong) reduction in availability of protein crops for the fodder industry, e.g. because of sudden disruption of soybean import and/or an increase in the price of soybean, and
- a (strong) reduction in availability or usability of EU grown crop products, e.g. as result of droughts or contamination with radioactive materials

Results of the study indicate that both types of calamities may have strong effects on the EU food sector by causing a considerable drop in animal production (see also summary of results in Table 1). This in turn may cause low availability of and high prices for animal products for human consumption, and the more so when the two types of calamities occur simultaneously, The effects of calamities were often not confined to the period that these calamities occurred, but also resulted in longer term fluctuations in prices and production, causing longer term uncertainties about prices.

While reduced availability of vegetable protein for feed affected mainly the pork and poultry/egg production systems, a reduced availability of roughage had strong impacts on the dairy and beef sectors only. This implies that options for mitigation of effects could partially be different for those two groups of animal production systems.

Evaluation of the situation where the production of biofuels was coupled to that of vegetable protein useable for human and animal consumption, resulted in less extreme reductions of production and increases in prices for animal products as it made the animal feed sector less dependent on imports of soybeans and thereby less exposed to import stops and price shocks of this commodity.

This raises the interesting question whether for the EU there could be a kind of 'optimal dependence combination' on EU based production and import of agricultural products as well as on the options to allow fast shifts between own production and import. Further research into this issue seems advisable as well as on the question on how such an optimum could be established through policy measures (e.g. regarding procedures and financing for setting-aside of agricultural land that specifically would be fit for production of products that otherwise would have to be imported).

The model used in this study provides likely aggregate responses. As a basis for concrete policy formulation, this is not sufficient. To gain insights into the range of possible individual responses and their sensitivity to policy measures, micro-simulations would be required. This should take the finances of individual farms into consideration, and thus provide some insights into the financial problems in the agricultural production sector that result from calamities. It should also distinguish the consumers by their consumption patterns and the effects of prices on these patterns. Finally, for both groups a regional disaggregation is in order. Such elaboration and underpinning of concrete policy measures, including financial measures, would require a different modelling approach.

A note on the scientific base of the model: where possible, the model is based on empirical information and scientific knowledge and logic. However, in fact very limited empirical data on responses in the food sector on trade and other shocks is readily available in scientific literature. Therefore we would like to suggest that research into the effects of and responses to such shocks would be of interest to provide a more empirical base for the type of study as in this report. Situations that could be studied include for example BSE in the UK, classical swine fever in Ireland, transport strikes in Italy (and maybe France), exchange rate shocks in Brazil, Thailand, Indonesia.

The following specific policy options were identified that may contribute to mitigation of the effects of calamities:

- **Stimulation of larger minimum stocks for grains and specifically soybean (and equivalents)**. Larger stocks lowered the price hikes of animal products during calamities. More research is warranted on whether such keeping larger stocks could be efficiently implemented, how it could be stimulated or enforced, and how costs of such additional stock keeping could be paid for and by whom.
- **Promotion of co-production of biofuel and protein**. In this study, it was shown that coupling of production of bio-fuel to that of protein reduced the effects of calamities. While such coupled production may reduce the dependency of the EU on soybean import, it would make the EU more sensitive to droughts and other events that reduce production. In addition, it may well be that such co-production, e.g. through protein rich crops, will not be the most efficient system to produce energy, nor to produce protein. Therefore, such coupling may very well not be included in policies that focus explicitly on energy or on protein. Enhancing the production of biofuel & protein, would most likely to some extent be at the expense of the area of grains in the EU. While this may affect the availability of grains in Europe in view of the current and expected surplus in grain production, it may affect the availability of grain to feed other parts of the world. More research into the positive effects of coupling biofuel and protein could contribute to the development of policies that favour a more integrated approach, with attention to resilience of the EU food production sector.
- **Allowing more use of animal products in feed.** Part of the animal production is not fit for human consumption. Allowing better use of this in animal feed, under conditions that would safeguard animal health and food safety, could reduce the dependence of EU on import or within EU produced soybean (or equivalents).
- **Facilitation of emergency support services to farmers during and after calamities**. In the model used in this study, the agriculture in the EU was in fact assumed to take place in one big farm with unlimited resources. Recovery of agricultural production after calamities was therefore swift in the model study. However, in reality, effects of calamities may include bankruptcy of individual farms, if not during the calamity (specifically in the pork and poultry/egg sectors) then thereafter (more likely in the dairy and beef sector, due to longer recovery times). Apart from direct economic effects, this may result in loss of production capacity for the longer term, e.g. because of loss of expertise, loss in market share, and in the EU becoming more dependent on agricultural production elsewhere. Research into the possible magnitude of this problem is needed to get better insight in the need to work on policies to develop and implement such emergency support services as well as to give guidance on the type of these services.
- **Price regulation and rationing of feed**. In times of scarcity of feed, stockholders of such feed will make large windfall profits, at the expense of livestock farmers and consumers. Alternative price regulation implies rationing of supply, and limited transmission of feed prices into product prices, with adverse effects for some firms. Policies on how to achieve such price regulation in times of emergency may need to be developed.
- **Developing emergency food rationing systems**. This study indicated that during and (shortly) after calamities, availability of food, specifically of animal origin, may be low. The resulting high prices may make it difficult or near impossible for the lower income groups in the EU to access sufficient protein rich food. A more detailed study into the importance of this problem, and on which groups in which countries would be most vulnerable could lead to better insight whether and where such rationing system would be needed.
- **Developing a reliable and transparent information policy.** The (expected) duration and severity of a calamity and the induced shortages in food and feed are crucial variables for producers, stockholders, retail and consumers to base their decision making on. Reliable and trusted information on this and on the size of available stocks may help rational decision-making and smooth supply, demand and prices.

- **Reduction in consumption of traditional animal products in favour of other sources of protein** (e.g. pulses, insects). In addition to the focus on production of protein rich food, also attention could be paid to the consumption of such foods. Current policies on stimulating the EU consumers to change their diets are not (yet?) having large impacts. Additional policies need to be developed, e.g. to increase prices of (certain) animal products (e.g. through taxation), and to actively stimulate production and marketing of protein rich food products that make more efficient use of inputs (e.g. pulses, fish, insects, mushrooms) and is healthier for the consumer.
- **Allowing farmers to use roughage from nature and set aside areas.** Low availability of roughage was found to have drastic effects on the dairy and beef sectors. It would be interesting to see in which situations giving farmers access to additional roughage coming from nature and set-aside areas would help to reduce these effects, and whether it is worthwhile to actively develop policies and rules on this issue.

This study focused on a situation where imports of protein could be disrupted, and where limited trade in animal products was taken into account. Only in this setting will trade restrictions on inputs have strong impact on consumer prices. Openness to trade in animal products helps stabilizing the consumer end of the market in case supply of inputs is disrupted (by trade or climatic events). However, the producer side may be in even worse trouble.

The dependence on imported protein exposes the European industry to the world market and consequently to possible disruptions in trade. However, at the same time, large-scale trade reduces the exposure to local climatic shocks that affect yields in particular regions, including the EU itself.

References

AFP, 2010. Europe bitterly divided over farm subsidies. Accessed 07/10/2010 at http://www.eubusiness.com/news-eu/farm-reform-budget.68d

Beever, D.E. & P.T. Doyle, 2007. Feed conversion efficiency as a key determinant of dairy herd performance: a review. Australian Journal of Experimental Agriculture 47: 645-657.

Berentsen, P.B.M., A.A. Dijkhuizen & A.J. Oskam, 1992. A dynamic model for cost-benefit analyses of foot-and-mouth disease control strategies. Preventive Veterinary Medicine 12: 229-243.

Bereskin, B., R.J. Davey & W.H. Peters, 1976. Genetic, Sex and Diet effects on pig growth and feed use. Journal of Animal Science 43: 977-984

Bindraban, P.S., C.P.J. Burger, P.M.F. Quist-Wessel & C.R. Werger, 2008. Resilience of the European food system to calamities. Report for the Steering Committee Technology Assessment of the Ministry of Agriculture, Nature and Food Quality, Report 211, Wageningen UR, Wageningen, The Netherlands. 82 pp + app.

Bindraban, P.S., C.P.J. Burger, P.M.F. Quist-Wessel & C.R. Werger, 2009. Resilience of the European food system to calamities. An inventory of studies on food security, calamities and their impact. Note 578, Plant Research International, Wageningen UR, Wageningen, the Netherlands. 74 pp + app.

Britt, J.S., R.C. Thomas, N.C. Speer & M.B. Hall, 2003. Efficiency of converting nutrient dry matter to milk in Holstein herds. Journal of Dairy Science 86: 3796-3801.

Byrne C. & M.B. Jones, 2002. Effects of Elevated Co2 and Nitrogen Fertiliser on Biomass Productivity, Community Structure and Species Diversity of a Semi–Natural Grassland in Ireland Biology & Environment: Proceedings of the Royal Irish Academy, 102 (3): 141-150.

Cannell, M. G. R. & J. H. M. Thornley, 1998. Temperature and CO2Responses of Leaf and Canopy Photosynthesis: a Clarification using the Non-rectangular Hyperbola Model of Photosynthesis. Annals of Botany 82: 883-892.

Duckworth J.C., R.G.H. Bunce & A.J.C. Malloch, 2000. Modelling the potential effects of climate change on calcareous grasslands in Atlantic Europe. J. Biogeog. 27, 347-358.

EU, Directorate-General for Health and Consumers, 2010. EU import conditions for fresh meat and meat products. Accessed 07-10-2010 on http://ec.europa.eu/food/international/trade/im_cond_meat_en.pdf

Eurostat, 2008a. Food: from farm to fork statistics. Eurostat pocket book. Office for Official Publications of the European Communities, Luxembourg. 190 pp.

Eurostat, 2008b. EU Economic Data Pocketbook 2-2008. Office for Official Publications of the European Communities, Luxembourg. 121 pp.

Evans, T., 2008. Europe's poultry imports to increase. Poultry International, October 2008: 14-15.

Ewert, , F., M.D.A. Rounsevell, I. Reginster, M.J. Metzger & R. Leemans, 2005. Future scenarios of European agricultural land use. I. Estimating changes in crop productivity. Agriculture, Ecosystems and Environment 107: 101-116.

FAPRI (no date) http://www.fapri.org/tools/elasticity.aspx

Fischer, G., Hizsnyik, E., Prieler, S. and H. van Velthuizen, 2007. Assessment of biomass potentials for biofuel feedstock production in Europe: Methodology and results. Work Package 2 - Biomass potentials for bio-fuels: sources, magnitudes, land use impacts. Deliverable D6: Methodology and assessment of biomass potentials in EU27+ under alternative future scenarios. REFUEL project report. IIASA, Vienna, Austria. 75 pp.

Fulkerson, W.J., J. Wilkins, R.C. Dobos, G.M. Hough, M.E. Goddard & T. Davison, 2001. Reproductive performance in Holstein-Friesian cows in relation to genetic merit and level of feeding when grazing pastures. Animal Science 73: 397-406

Gelder, J.W. van, K. Kammeraat & H. Kroes, 2008. Soy consumption for feed and fuel in the European Union. A research paper prepared for Milieudefensie (Friends of the Earth Netherlands). Profundo, Castricum, the Netherlands.

Grainger, C. & M.E.Goddard, 2004. A review of the effects of dairy breed on feed conversion efficiency – An opportunity lost? Animal Production in Australia 25: 77-80.
Grime J. P., V. K. Brown, K. Thompson, G.J. Masters, S.H. Hillier, I.P. Clarke,A.P. Askew, D. Corker &J. P. Kielty. 2000. The Response of Two Contrasting Limestone Grasslands to Simulated Climate Change. Science 289 (5480): 762 - 765
Havenstein, G.B., P.R. Ferket & M.A. Qureshi, 2003. Growth. Livability, and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry Science 82: 1500-1508.
Horne van, P.L.M., 2009. Production costs of broiler meat; An international comparison, LEI, Report 2009-004; ISBN 978-90-8615-300-8 The Hague. http://www.lei.dlo.nl/publicaties/PDF/2009/2009-004.pdf
Hoste, R. & L.F. Puister, 2009. Productiekosten van varkens: een internationale vergelijking. LEI, Wageningen UR, Rapport Werkveld 4. Sectoren en bedrijven 2008-082, 72 pp.
Hyun, Y., M. Ellis, G. Riskowski & R.W. Johnson, 1998. Growth performance of pigs subjected to multiple concurrent environmental stressors. Journal of Animal Science 76:721-727.
IFIP, 2006. "Le Porc par les Chiffres 2006", Institut de la Filière Porcine, France.
Johnson, D.E., C.L. Ferrel & T.G. Jenkings. The history of energetic efficiency research: where have we been and where are we going? Journal of Animal Science 81: E27-38.
Kammann C., L. Grünhage, U. Grüters, S. Janze & H.-J. Jäger, 2005. Response of aboveground grassland biomass and soil moisture to moderate long-term CO2 enrichment. Basic and Applied Ecology 6(4): 351-365
Lüscher, A., M. Daepp, H. Blum, U.A. Hartwig & J. Nösberger, 2004. Fertile temperate grassland under elevated atmospheric CO2—role of feed-back mechanisms and availability of growth resources. European Journal of Agronomy, 21 (3): 379-398.
McGuirk, B. 2000. Genetic changes in ruminants: Historic trends and future perspectives. In: 'The challenge of genetic change in animal production'. Proceedings of an Occasional meeting organized by BSAS. BSAS Occasional publication number 27, eds WG Hill, SC Bishop, B McGuirk, JS McKay, G Simm, AJ Webb.
McKay, J.C., N.F. Barton. A.N.M. Koerhuis & J. McAdam, 2000. The challenge of genetic change in the broiler chicken. In: 'The challenge of genetic change in animal production'. Proceedings of an Occasional meeting organized by BSAS. BSAS Occasional publication number 27, eds WG Hill, SC Bishop, B McGuirk, JS McKay, G Simm, AJ Webb.
Merks, J.W.M., 2000. One century of genetic changes in pigs and the future needs. McKay, J.C., N.F. Barton. A.N.M. Koerhuis & J. McAdam, 2000. The challenge of genetic change in the broiler chicken. In: 'The challenge of genetic change in animal production'. Proceedings of an Occasional meeting organized by BSAS. BSAS Occasional publication number 27, eds WG Hill, SC Bishop, B McGuirk, JS McKay, G Simm, AJ Webb.
Porter, J.R. and M. Gawith, 1999. Temperatures and the growth and development of wheat: a review. Eur. J. Agron. 10, pp. 23–36.
Porter, J. R. & M.A. Semenov, 2005. Crop responses to climatic variation. Phil. Trans. R. Soc. B 360: 2021–2035.
Preisinger, R. & D. K. Flock, 2000. Genetic changes in layer breeding: historical trends and future prospects. McKay, J.C., N.F. Barton. A.N.M. Koerhuis & J. McAdam, 2000. The challenge of genetic change in the broiler chicken. In: 'The challenge of genetic change in animal production'. Proceedings of an Occasional meeting organized by BSAS. BSAS Occasional publication number 27, eds WG Hill, SC Bishop, B McGuirk, JS McKay, G Simm, AJ Webb.
Quiniou, N., J. Noblet, J.-Y. Dourmad & J. van Milgen, 1999. Influence of energy supply on growth characteristics in pigs and consequences for growth modelling. Livestock Production Science 60: 317-328.
Rauw, W.M., E. Kanis, E.N. Noordhuizen-Stassen & F.J. Grommers, 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livestock Production Science 56: 15-33.

Regmi, A., M.S. Deepak, James L. Seale Jr., Jason Bernstein (2001) Changing Structure of Global Food Consumption and Trade. ERS, USDA, WRS -01-1

Schär, C., P.L. Vidale, D. Lüthi, C. Frei, C. Häberli, M.A. Liniger & C. Appenzeller, 2004. The role of increasing temperature variability in European summer heatwaves. Nature 427: 332-336

Smit, A.L., P.S. Bindraban, J.J. Schröder, J.G. Conijn & H.G. van der Meer, 2009. Phosphorus in agriculture: global resources, trends and developments. Report to thte Steering Committee Technology Assessment of the Ministry of Agriculture, Nature and Food Quality, the Netherlands. Report 282, Plant Research International, Wageningen University and Research Centre, Wageningen, the Netherlands. 36 pp.

Smit, H.J., Metzger, M.J. and F. Ewert, 2008. Spatial distribution of grassland productivity and land use in Europe. Agricultural Systems 98, 208-219.

Stones, M., 2010. Europe to lead world dairy quality standards and welfare, says expert. PPJ Gazette. Accessed 7/10/2010 at http://ppjg.wordpress.com/2010/09/24/jsut-in-time-for-s-510-the-eu-will-set-world-dairy-standards/

Thornley, J.H.M. & M.G.R. Cannell, 1997. Temperate Grassland Responses to Climate Change: an Analysis using the Hurley Pasture Model. Annals of Botany 80: 205-221

Trnka, M., M. Dubrovský, D. Semerádová, and Z. Zalud, 2004. Projections of uncertainties in climate change scenarios into expected winter wheat yields. Theor. Appl. Climatol. 77: 229-249.

Vaccari, D.A., 2009. Phosphorus: A looming crisis. Scientific American 300 (6): 42-47.

Van Cauwenberghe, S., M. Peisker & M. Pack, 2003. 10.- The role of amino acids in an environmentally friendly competitive European pig production. In FEFANA: Protein requirements and supply for a competitive European pig production in 2010: 44-48. Brussels, March 18, 2003.

Van Dijk, T., 2008. Exporting eggs and egg products to the EU. Requirements and opportunities for transition countries. UNECE, Geneva. 41 pp.

Weidema, B.P., Wesnaes, M., Hermansen, J., Kristensen, T. en N. Halberg. In Eder, P. & L. Delgado (Eds.), 2008. Environmental Improvement of meat and Dairy Products. JRC Scientific and Technical Reports. http://ftp.jrc.es/EURdoc/JRC46650.pdf

Wheeler, T.R., P.Q. Craufurd, R.H. Ellis, J.R. Porter & P.V.V. Prasad, 2000. Temperature variability and the yield of annual crops. Agriculture, Ecosystems & Environment 82 (1-3): 159-167.

Witzke, H.-P. and A. Zintl (2005) CAPSIM, Documentation of Model Structure and Implementation, Working papers and studies, European Communities

WRR, 1995. Sustained risks: a lasting phenomenon. Netherlands Scientific Council for Government Policy. Reports to the Government 44. The Hague, the Netherlands. 205 pp.

Appendix I
Current agricultural production EU

I.1 Land use and productivity

Total EU-27 territory covers 432 million hectares, of which 90% rural areas comprising agricultural land and forest. A total of 184 million hectares (43%) is reported as utilised agricultural area (UAA) in 2005 (Table 18). Majority of the UAA (59%) is arable land, 34% and 7% are dedicated to permanent grassland and permanent crops (orchards, vineyards, olive plantations) respectively. Forests and other wooded land cover approximately 160 million hectares (35% of the EU territory), of which 117 million hectares are available for wood supply (EC, 2007f). In 2005, the total set-aside land was reported to be 7 million hectares, of which 4 million hectares were obligatory set-aside.

Table 18. EU: area and agricultural area by land use (mio ha), 2005.

(mio ha)	EU-15	EU-25	EU-27
Total area	323.5	397.3	432.3
[1]Utilised agricultural area	130.5	164.1	183.6
Of which:			
[2]Arable land	72.6	97.1	109.4
[3]Permanent grass-land	48.1	57.1	63.6
[4] Land under permanent crops	11.6	11.6	12.2

[1] Utilised agricultural area (UAA): total area used for crop production, described as arable land including temporary grass and fallow and green manure, permanent grassland, land under permanent crops, crops under glass and other utilized agricultural areas.
[2] Arable land: land worked regularly, generally under a system of crop rotation, which includes fallow land.
[3]Permanent grassland and meadow: herbaceous forage crops permanently (≥ 5 years), cultivated or naturally, that is not included in the crop rotation on the holding; used for grazing or mowed for silage or hay.
[4]Permanent crops: crops, other than permanent grassland, not grown in rotation for a long period.
Source: Eurostat

Arable land
Over half of the arable land is cultivated under cereals, one of the most important crop groups (Figure 25). With a production quantity of over 287 million tonnes, the EU-27 accounted for 12.5 % of the world production of all cereals including rice in 2005. Wheat is the most widely grown cereal type in the EU accounting for nearly half of the production quantity in 2004. Over 60% of the domestic use of cereals in the EU-27 is animal feed.

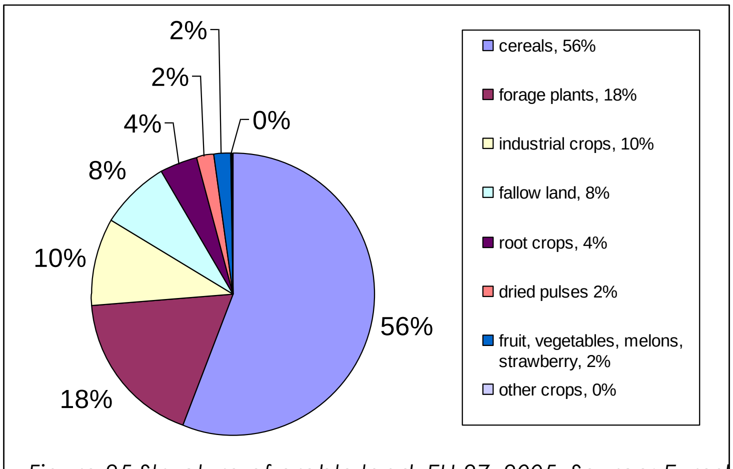


Figure 25 Structure of arable land, EU-27, 2005. Source: Eurostat

Other land uses important for this study, include silage crops, pulses/protein crops and soybean.

Table 19 Area and average yield, and production of selected arable crops in the EU-27 in 2005.

Crop	Area (mio ha)	Average yield (t/ha)	Usable production (mio tons)
Cereals – total	51.5	4.9	253.2
Wheat[1]	23.3	5.3	123.4
Barley[1]	13.1	4.0	52.6
Maize[1]	6.1	7.8	47.7
Silage[2]	5.2		
Pulses/protein crops	1.4		
Soy	0.4	2.7	1.1

[1] EU-25; [2]excluding grass silage
Source: Eurostat

Grasslands
Grassland systems in Europe are diverse, ranging from extreme Tundra vegetation in the far North to dry Mediterranean in the South. A classification for forage and grassland types (Table 20) is provided by Eurostat as reported by Smit *et al* (2009), which defined permanent as not being (re)sown for five years. This classification includes natural grasslands, and herbages and covers the greater part of the grassland area in Europe. Permanent grassland can be used for both grazing (pastures) and cutting (meadows). Temporary grasslands are newly sown meadows. Temporary grassland is often classified under arable crops. Therefore, it is not always possible to know the area for these crops in each country and region.

Grasslands, which cover more than one third of the utilized agricultural area of the EU-27, have a basic role in feeding herbivores and ruminants and provide important ecosystems services. Grassland productivity is affected by climatic factors such as rainfall and temperature. The role of management and the underlying effect of technology change on grassland are not well-described (Smit *et al.*, 2008).

Table 20 Definitions of forage categories as provided by Eurostat.

<table>
<tr><td rowspan="5">Forage plants</td><td rowspan="5">Green fodder from arable land</td><td rowspan="3">Annual green fodder</td><td colspan="2">Fodder maize</td></tr>
<tr><td rowspan="2">Other annual green fodder</td><td>Fodder beets</td></tr>
<tr><td>Other root crops</td></tr>
<tr><td rowspan="2">Perennial green fodder</td><td rowspan="2">Temporary grasses and grazing</td><td>Temporary grasses</td></tr>
<tr><td>Temporary grazing</td></tr>
</table>

			Clover and mixtures
			Lucerne
			Other legumes
	Green fodder from permanent grassland	Permanent pastures	Herbages
			Rough grazing
		Permanent meadows	

Source: Smit *et al.*, 2008.

In Western Europe, permanent grassland is an important land use system, covering more than 45% of the UAA in the Netherlands, Luxembourg and UK. In Central Europe, grasslands are especially important in mountainous areas like in Austria and Slovenia (> 50 % UAA), while lowlands grasslands covers just 20-25 % of the UAA. In the Mediterranean, grassland is an important land use and mainly grazed by sheep and goats (Smit *et al.*, 2008).

The highest productivity, about 10 t/ha is achieved in the Atlantic zones which comprise North western Spain, Western France, Ireland, Wales and England, the Benelux, the North of Germany and the South-western part of Norway. The Netherlands has the highest recorded yields, which is the result of a suitable climate and highly intensive pasture use. In addition, the high fertilization rate is a major determinant of attained yields. The grassland species in these ecosystems are usually *Lolium perenne* and *Poa* spp.

Regions with lowest productivity are located in the Mediterranean, with yields of about 1.5 tons/ha due to severe moisture stress. When irrigation is applied, yields as high as 15 tons/ha are achieved. Mediterranean grasslands are highly diverse ecosystems, consisting of grass species annual plants and herbaceous species.
The Scandinavian countries are also low in productivity but slightly higher productivity is achieved due to more intensive management that involves frequent grass sowing, often with *Phleum pratense*. Central European countries, such as Germany, reach yields of about 6 tons/ha, while Poland and Czech Republic and Slovakia achieve around 4 t/ha. In Hungary, Bulgaria grassland in steppe conditions yield about 1.5 tons/ha. In mountainous areas with greater precipitation, higher yields are achieved. Grass species used in Central Europe are often *Festuca* or *Agrostis* spp. (Smit *et al.*, 2008).

Variation in productivity between years can be large, e.g. with standard deviation of 0.6 ton/ha in France. Most likely, this variation is due to climate. Especial droughts have an impact on productivity, as happened in 1976 and 2003, when both France and Germany showed significant drops in productivity.

I.2 Pig farming and feed requirement in the EU

After China, the EU is the largest production region for pork on a global scale (IFIP, 2006). In the EU, pork production consumes about 36% of total soybean meal used.
Pig production in Europe takes place mainly in large specialised units following the same system, although differences may occur in feed composition. Currently, two main systems may be distinguished (Weidema *et al*., 2008):
- one system with optimised feed, which is assumed to cover the situation in North-Western European countries such as Germany, France and Denmark and Southern European Countries like Spain;
- one system with reduced feed efficiency, which is assumed to cover roughly the situation in Poland and other Eastern European countries

The required pig feed (complete feed requirement) was calculated, based on the following parameter values: a pig carcass yields about 77% meat (Van Cauwenberghe *et al.*, 2003). The feed conversion rate is 3.0 for the EU-15 and 3.3 for the EU-12 (Van Cauwenberghe *et al*., 2003; Hoste and Puister, 2008; Weidema *et al.*, 2008).

Table 21 Key assumptions for pig production systems in Europe.

System	**'Intensive' (EU-15)**	**'Low efficiency' (EU-12)**
Total annual production volume (net production in mio t)	18.1	3.8
Pig feed conversion rate (kg dw feed / kg pork live weight)	3.0	3.3
Required pig feed (mio t)[1]	70.5	16.3

[1]. Including consumption by piglets.

Breeding sows and fattening pigs consume about 107 million tons, comprising about 63.6 million tons cereals and 13.9 million tons soybean meal (Table 22).

Table 22 Pig production in EU-27; total feed intake and share of cereals and soybean meal in the ration.

	Total annual feed intake (mio tons)	Cereal inclusion rate (%)	Soybean meal inclusion rate (%)	Cereal in ration (mio tons)	Soybean meal in ration (mio tons)
Pigs	87	70	20.0	60.9	12.2
Breeding sow					
Gestation	12	8	3.0	1.0	0.4
Lactation	8	21	16.5	1.7	1.3
Total	107			63.6	13.9

I.3 Egg and Poultry sector

The poultry population in the EU counted 1453.5 million heads in the EU in 2005, of which broilers 770.2 million heads, layers, 478.6 million heads and other poultry 204.7 mio heads (Source: Eurostat).

Table 23 Feed intake and production of meat and eggs

	Population (mio heads)	Production[1] (mio t)	Feed conversion (kg feed/kg product)	Feed intake (mio t)
Broilers (meat)	770.2	11.2	1.8	22.9
Layers (egss)	478.6	6.3	2.1	13.2
Total	1248.8			36.1

[1] Poultry meat: conversion from carcass weight to retail weight: 0.88 (OECD-FAO, 2001)

Table 24 Composition of feed for broilers and layers.

	Total annual feed intake (mio tons)	Cereal in ration (%)	Soybean meal In ration (%)	Cereal in ration (mio tons)	Soybean meal in ration (mio tons)
Broilers	22.9	45.	36.8	10.3	8.4
Layers	13.2	60.	22.4	7.9	3.0
Total	36.1			18.2	11.4

I.4 Cattle

Dairy farming is concentrated on the coast of continental Europe from the Normandy region to Denmark. The area in and around the Alps are a second hotspot. Meat production in the form of beef cattle and sheep is dominant in the North and West of the British Isles, Central and Southern France and the Mediterranean.

Of the total milk production in EU-25, 85 % is produced within EU-15 countries. Five countries – Germany, France, United Kingdom, Netherlands and Italy – produce more than 60 % of the EU-25 milk (Eurostat). Outside EU-15 Poland is the main producer with 8 % of EU-25 production. Among and within these countries, production conditions differ.

More than 90 % of the total EU-25 consumption of beef/veal is produced in EU-15 countries. An increase is expected in the import (Eurostat). The major suppliers (in descending order) are France, Germany, Italy, United Kingdom, Spain, and Ireland, representing together 75 % of total EU-25 production. The beef systems in these countries therefore largely represent the total systems for beef production. Beef production systems differ concerning the age and weight at which animals are slaughtered, the method of feeding, and the type of housing.
Two main categories exist, depending on whether the animals come from dairy farms or from suckler herds.

II Appendix II
Model description

II.1 Modelling the economics of the feed system

Free market regime.
In this regime, imports and exports are free. On the initial assumption that trade is costless, the domestic prices are equal to world market prices. This amounts to perfect arbitrage. Provisionally, we make the additional assumption that the trade amounts to small quantities relative to world trade in the commodity, and that therefore the world price can be taken as given.
Local production and stocks enter into the market at this price. How much is traded depends on the local production and stocks on the assumption that local demand is met first by local production and available stocks.
Some issues arise due to the quarterly nature of the model. Local production (plus stock) at the end of the harvesting period may or may not exceed the requirements for the year, exports or imports will balance supply and demand. How much of this trade is done in each quarter?

We distinguish first the case of an exporter and then look at mixed exporter/importer case.

For an exporter, it appears reasonable to assume stocks after harvest to be depleted by the end of the crop year, and to spread this depletion of the stocks gradually over time. An example is the level of stocks of soybean in the USA from December to September every year (Figure 26).

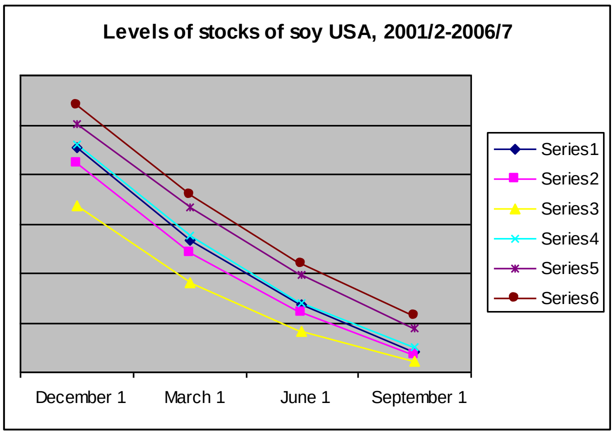


Figure 26 Levels of stocks of soybean, USA, by quarter over the years 2001/2-2006/7; 'series1' corresponds to 2001/2, etc.

Thus, if availability exceeds demand we may take as a first approximation that the stocks will diminish over periods 1, 2 and 3 after the harvest period by a third of the difference between opening stocks and minimum stocks.

In case production plus stocks are insufficient to cover the whole year's demand for the commodity, empirical evidence points out that imports and exports are spread rather equally over the months of the year, which indicates that domestic stocks are depleted gradually over the year. Hence, stocks are not used first, before imports come in. This smooth pattern is demonstrated in Figure 27 that shows the EU-27 imports of feeding stuff (except un-milled grains) by quarter, taken as a percentage of the whole calendar year import. On average the shares are 25, 25, 24 and 26% for quarters 1 to 4.

The implication is that we can assume that also in cases where stocks plus production are not enough to cover the year's needs, the use of domestic production take place gradually over the year. Hence, again we can use the approximation that one third of the accumulated stocks at the end of the harvest quarter will be used in each of the following quarters, and that imports adjust.

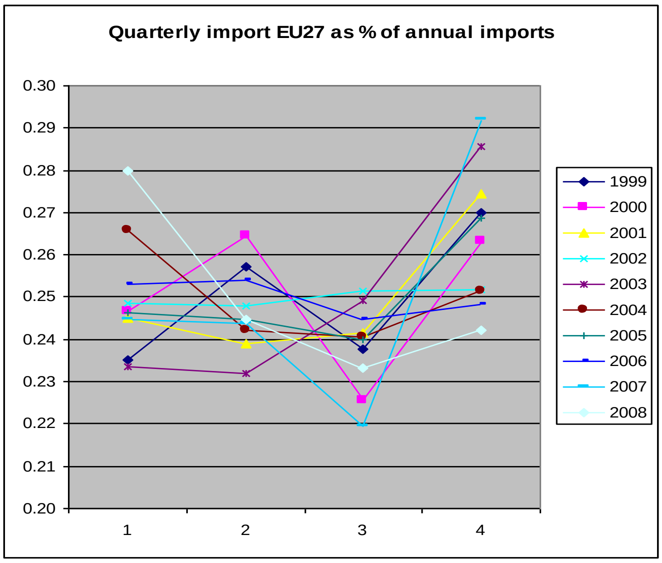


Figure 27 Quarterly shares of EU27 feeding stuff import quantities.

The procedure then is model imports in quarter *t* as equal to demand in *t*-1, minus what can be supplied from stocks plus production. This latter supply is set equal to a quarter of annual production plus opening stocks minus the minimum level of stocks. The corresponding formula – using *Z* for opening stocks – is $(Z\text{-}Z^{min})/4$ for the first quarter after the production quarter, and divided by 3, 2 and 1 in each subsequent quarter.
In case stocks fall below the minimum, the formula is changed by replacing the term between parentheses by just *Z*.

Prices could be adjusted to reflect the net importer or net exporter status, with obviously higher prices for the net importer's case. The relative amount that is exported or imported does not matter for this price difference, however. For the difference we assume a percentage of 5%. Thus, when exporting, domestic prices are 5% below the world market price, and when importing these are 5% above the world market price.

For the grain market this leads to

supply
release from previous stocks R_t:
$(Z_0\text{-}Z_{min})/4$ for quarter 4 in a calendar year
$(Z_0\text{-}Z_{min})/3$ for quarter 1 in a calendar year
$(Z_0\text{-}Z_{min})/2$ for quarter 2 in a calendar year
$(Z_0\text{-}Z_{min})$ for quarter 3 in a calendar year
in case $Z_0 < Z_{min}$, Z_{min} is set to 0 in the above equations.

Production
Produced is realized in the third quarter of the year. Yields per ha are taken to be slightly sensitive to prices (elasticity of 0.1, source FAPRI), and may vary in a random way. The area sown (in quarter 2) is sensitive to prices. Indicative prices are taken to be those of the previous harvest season: prices in quarter 3 of the previous year.

For the purpose of predicting area adjustments to large price changes, we follow a special approach. Typically, the current models distinguish an own price elasticity of supply of grain of 0.1 and a cross-price elasticity with respect to oil seed prices of minus 0.5 (source: FAPRI model). Our purpose is, however, not served well by including such an assumption. The implication of the above elasticities would be that a price rise of oilseeds by 10% would lead to a drop in wheat area by 5% or approximately 2.5 million ha. The corresponding model parameters for oil seed (or more precisely the soybean area) would, however, generate an increase in area of 4% of the soybean area, or 4% of 2 M ha, which is only 80,000 ha.
To solve this asymmetry in the effects on grain and soybean area, we model the reactions in two stages, one is a change in total area (grains + soy), with an elasticity of 0.2; and the other is a change in ratio of grain to soybean area in response to a change in the ratio of the prices with an elasticity of 1.

Therefore, the **total area sown** in quarter 2 of year *t* is a function of the prices in quarter 3 of year *t*-1:

$$A_{t,2} = C.\left(\overline{P}_{t-1,3}\right)^{0.2}$$

The constant C is set to the initial, total area of 53.8 million ha (for 2005).

And the ratio of grains to soybean area is given by

$$\frac{A_t^g}{A_t^s} = c.\left(\frac{P_{t-1}^g}{P_{t-1}^s}\right)^1$$

The constant c here is set to the initial ratio of 32.1. For 2005, this is 51.5 million hectares.
The actual area of each crop, grain or soybean, can be calculated from the two equations.
The implied elasticities depend on the share: the lower the share, the higher the elasticity. At the prevailing ratio of grain to soybean area of 25:1, the area elasticity of grains (w.r.t. grain prices) is 0.23; the own-price elasticity of soybean area is 0.97. We are working, therefore, with stronger price responses than is assumed for business-as-usual models. However, note that we hardly include other area than grain and soybean.
The implied cross-price elasticities are -0.03 and -0.77 for grains and soybean area respectively.

Yields

$$Y_{t,3} = C_1\left(P_{t-1,3}^g\right)^{0.1}.[0.95 + random(0\ to\ 0.1)]$$

The constant C_1 is set to the normal yield corresponding to the chosen scenario. For 2005 this is 4.92 ton per ha.
To simulate calamities, an adjustment factor for this yield can be chosen to reflect droughts etc.

Production then follows as

$$Q_{t,3} = A_{t,2}Y_{t,3}$$

Imports – if allowed at all by the choice of calamity – are set equal to previous consumption levels minus the supply from stocks.

$$M_t = D_{t-1} - R_t$$

Demand *D* consists of demand for food D^c, and demand for feed D^f. Food demand depends on the price of the previous quarter

$$D_t^c = d\ .\left(P_{t-1}^g\right)^{-0.26}$$

The variable *d* is set equal to the initial grains consumption of the chosen scenario. The elasticity is taken from FAPRI (and actually refers to wheat). In scenarios where the EU is autarkic in grains, we apply a smaller elasticity (-0.13) to reflect the reduction in alternative sources of food and to have grains preferentially destined to human consumption.
Feed demand D^f follows from the various demand schedules that are specific for each type of cattle, and will be discussed there.

Stock changes result from the addition of production plus net imports minus consumption for food and feed:

$$Z_t = Z_{t-1} + Q_t + M_t - D_{t-1}$$

Note that M includes the release from stocks.

Finally, **prices** that are relevant for the next period result from setting domestic prices equal to world market prices plus or minus a trade margin of 5%, with the plus or minus depending on whether net imports or exports occur.

$$P_t^g = P_t^{g,w} * (1 \pm 0.05)$$

No trade

If no free trade is possible, stockholder's behaviour changes. Supply out of stocks no longer follows the earlier pattern of gradual depletion of stocks until the next harvest, but is now more careful. While the assumptions can be changed, the basic assumption is that planned release of stocks occurs with a view to maintaining the stock for two years. Reason is that stocks can be more easily kept in store than repurchased later. This planned release affects the price via some 'planning elasticity', but actual consumption may exceed the planned release. Thus, for the price formation in times of autarky, it is assumed that prices should adjust so as equate – by approximation – demand to the planned supply. However, actual demand may be less or more, because it follows the various demand schedules of the animal sectors. Resulting stock levels may differ from the planned level and prices will accommodate this. Thus, the planning involves: 1. setting a target for supply next quarter; 2. setting a price that is expected to bring demand to this level; 3. adjust stocks in view of actual developments.

If the original demand function is $D = d.P^{-\varepsilon}$ with $-\varepsilon$ the demand elasticity, then to make this equal to an actual supply of *S*, we need a price of $(S/d)^{-1/\varepsilon}$. In this formula, the parameter *d* is approximated by its equivalent in the previous period, of which we know the value. The demand elasticity used for planning is only approximate.
In a case (say period 0) with information on values for all variables and the elasticity, d can be derived from:

$$d = \frac{D_0}{P_0^{-\varepsilon}}$$

Hence, to have a price that equalizes demand to a given supply S_1, we need

$$P_1 = S_1^{-1/\varepsilon} \left(\frac{D_0}{P_0^{-\varepsilon}} \right)^{1/\varepsilon} = \left(\frac{S_1}{D_0} \right)^{-1/\varepsilon} P_0$$

In a more general setting: price in quarter *t* equals price in quarter *t*-1, adjusted by a factor that is responsive to the new level of supply, relative to the old level of demand.
Thus, the sequence at the start of a calamity is that first stocks are assessed. These are then divided into equal volumes of quarterly supply until the end of next year. The prices in each quarter then lead to demand in the quarter being approximately equal the given supply. The cattle sector responds to these prices.

This procedure presumes that all supply must be consumed by the sector, and it assumes that there is no need to look beyond year 2. We discuss both presumptions and adjust the model accordingly.

In case of a net exporter, a sudden disruption in international trade causes a surplus of the commodity. While prices should obviously fall, it need not be so that in this case all supply must be absorbed by the sector within a year. Hence, supply from stocks will not strive toward releasing all stock in a year. We assume two years for this process.
In case of a net importer, the trade disruption causes supply to fall short of demand; prices should rise by enough to establish a new equilibrium of demand and supply. In fact, as supply is very tight, prices may have to rise quite out of the normal range. In these special conditions, the usual elasticities do no longer apply. Working with normal demand elasticities would not reduce demand to levels that are required (say to a quarter of normal supply) without raising prices to astronomic levels. Therefore, we introduce demand elasticities that rise when prices go to extremes.
In stead of a normal demand function with a constant elasticity

$$D_t^c = d\ .\left(P_{t-1}^g\right)^{-\varepsilon}$$

we have

$$D_t^c = d\ .\left(P_{t-1}^g\right)^{-\varepsilon P_{t-1}^g}$$

One can easily verify that for normal prices, which we set at 1, the elasticity is what it is in normal conditions. For high prices, the demand response is however taken to be stronger than normal.
Figure 28 shows two demand functions. One with a simple elasticity of -0.3, the other with an elasticity of -0.3 times p. The adjusted function shows that a price of 2 leads to a demand of 0.66, compared to a demand of 0.81 for a constant elasticity.

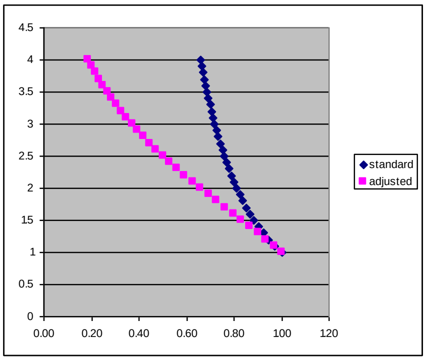


Figure 28 Effect of two elasticities on price (y-axis) and demand (x-axis) relations for grains (see text)

The procedure for setting a price in case of no trade is to 'predict' demand for normal (world market) prices, and also to 'predict' production and the normal release from stocks, and then to check if predicted supply meets demand.

release from stocks $R_t^{pred} = 0.5\left(Z_{t-1} - Z_{\min}\right)/n,\ n = 4,3,2,1\ \textit{for quarter} = 4,1,2,3$

autarky price: $P_t^g = \left(P_{t-1}^g\right) * \left(\frac{R_t^{pred}}{D_t^{pred}}\right)^{1/0.3}$

The predicted demand in this formula is set equal to standard demand levels, as recorded before the calamity. At this price, demand only approximately equals supply, with any discrepancies solved in later quarters, and made possible by the use of the minimum stocks that act as a buffer. When the thus generated prices are very high (higher than 1.4) a formula is used to translate these prices into more realistic prices, conformable to the assumption that the elasticity increases with the price. The approximate formula for P_{gen}>1.4 is

$$P_{trans} = 1.196 + 0.586 \ln P_{gen} - 0.014(\ln P_{gen})^2$$ (see Figure 29)

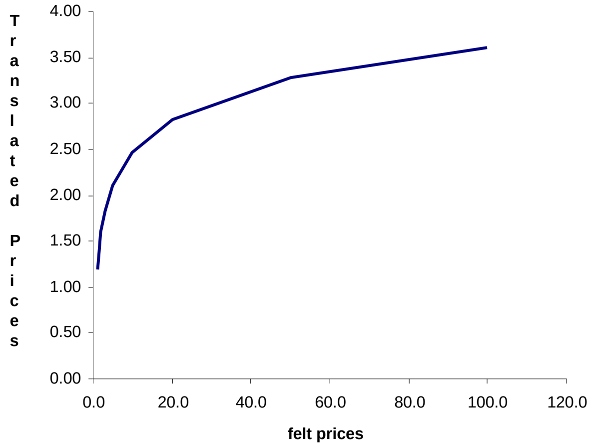


Figure 29 Relationship between extreme prices that should apply to constant elasticities ('felt prices') and those that correspond to elasticities linearly increasing with p ('translated prices').

Consumption (using constant elasticities) is influenced by the 'felt' prices, which implies that consumption is actually characterized by an elasticity that is increasing in prices. Production decisions are influenced by the 'translated' prices directly.

The oil seed market

World market prices dominate this sector as imports largely outstrip domestic production. Hence, prices are dictated by the world market. Cultivated area responds to prices of oil seeds and grains in the previous year (similar to the case for grains), and yield responds to oil seed prices. Demand is derived from feed demand by the various types of cattle. Domestic prices are allowed to differ slightly from the world market prices in response to the ratio of carry-over stocks to demand of the previous quarter, with a flexibility of -0.05.

Thus, we have area determined by the relationships described above for grains.

Yields in the 3rd quarter of year *t*

$$Y_{t,3} = C_1 \left(P^s_{t-1,3}\right)^{0.1} .[0.95 + random(0\ to\ 0.1)]$$

The constant C_1 is set to the normal yield corresponding to the chosen scenario. For 2005 this is 2.85 ton per ha. In case of calamities, this level of yield can fall to a chosen percentage to reflect droughts etc.

Production then follows as

$$Q_{t,3} = A_{t,2} Y_{t,3}$$

Net Imports of oil seed follow the same regime as that of grains. It equals last period's consumption (as a proxy of this period's demand) minus what can be supplied from previous stocks. This out-of-stock supply follows the same formulas as for grains, except that a minimum stock level always applies, even to the extent that if previous levels were below the minimum a negative out-of-stock supply results. This is related to the market: oil seeds are imported and a transaction stock must be maintained to smooth transport, processing and trade.

Prices follow world market prices, but if changes in stock-to-consumption ratios occur, prices adjust slightly. If minimum levels are required that equal one quarter's consumption the price ratio between domestic and world market prices will be unity, but if lower stocks are needed, higher domestic prices will prevail and v.v. for higher minimum stock levels. Rationale is that lower stock levels carry a danger of stock-out, and hence cause prices to be higher.

No trade

A regime with trade restrictions for oil seeds would be much more dramatic than for grains. Actually, Europe normally has a surplus of grains, but a tremendous shortage of oil seeds. No normal economic market behaviour, i.e. responses to price signals can achieve a change in demand dramatic enough to accommodate a sudden blockage in oil seed supply. To reach a consistent result, we simulate prices to go to exorbitantly high levels, to reflect scarcity, i.e. difficulty of securing supply. Under the assumption of elasticities that are responsive to these high prices too, we then generate translated prices and these affect supply responses.

An important element is the release of stocks in these times of scarcity. As derived and explained in section 7.2, a rational assumption is that this release is spread equally over the quarters of the period of shortage. It takes into account what production will be forthcoming. In the standard case, where only little area of soybeans is cultivated in the EU, the predicted supply response is dependent on the information available:

- in the first quarter, no scarcity prices are yet observed. Stockholders take 1.5 times the previous harvest as a 'guesstimate' for upcoming production
- in Q2 and Q3, the Q1-price of soybean acts as a guide: with an elasticity of 1, the best guess is the previous crop times the price in Q1
- in Q4-Q7, the recent harvest of Q3 is known, and is taken as a predictor of the next harvest in Q7 (3rd quarter of year 2), but a factor of .75 is used to prevent stockholders from selling the crop before it is available
- in Q8, no new harvest is expected

Prices are established that make predicted demand equal to this release from stocks. Predicted demand is simply the standard import before the calamity, adjusted for increases in prices of pork and poultry. A demand elasticity of -0.4 is used in this price setting stage. This elasticity would correspond to the value that applies to price increases of around 50%, which seems fair as a heuristic for the stockholders.

In the case of bio-fuel production, the scheme is adjusted. Areas under soybeans (or other protein crops) are much higher than in the standard case, and stockholders should no longer work with a unitary elasticity, nor is it sensible if they set their predicted harvest equal to 1.5 the previous, pre-calamity, level.

In fact, imports are not that important anymore. They represent only 10% of what is demanded, and it seems logical to start from business-as-usual and see if the market adjusts by itself to lower than usual levels of stocks.

Thus, release from stocks is simply the normal quarter of the seasonally adjusted stocks above the minimum. Prices no longer equal world market prices, however, and are derived from

$$P_t^s = \left(P_{t-1}^s\right) P_{t-1}^{p+p} \left(\frac{R_t^{pred}}{D_t^{pred}} \right)^{1/0.4}$$

where R^{pred} is the normal release from stocks, and D^{pred} is the predicted demand, taken to be standard demand of 8000. The outcome is multiplied by the average prices of pork and poultry, P^{p+p}

of the previous quarter to account for demand shifts. Downward price adjustments are limited to 10% per quarter.

ROUGHAGE

The roughage market is modelled without imports and exports. Supply comes from areas 'sown' every year (between apostrophes because this includes permanent grassland). This area yields roughage in the 2nd and 3rd quarter of the year. The output is stocked to provide the fodder in the other two quarters. The price is, generally, not very sensitive to changes in demand and supply and is modelled to respond to the ratio of actual stocks and the level of stocks normal for the quarter. The flexibility is -0.1. If stocks are insufficient to meet the upcoming demand of the next quarter, prices respond to the ratio of prospective demand and actual stocks, with a flexibility of 0.2.

In equations:

The **area sown** in quarter 2 of year *t* is a function of the average prices in the previous year *t*-1:

$$A_{t,2} = C_t \cdot \left(\overline{P}^r_{t-1}\right)^{0.1}$$

The variable C is set to the previous area. For 2005 this is 76 million hectares.

Yields in quarter 2 and 3

$$Y_t = C_1.[0.95 + random(0\ to\ 0.1)]$$

The constant C_1 is set to the normal yield corresponding to the chosen scenario. For 2005 this is 2.68 ton of dry matter per ha in each of the two quarters (5.37 ton per year).

Production then follows as

$$Q_{t,2} = A_{t,2} Y_t$$

$$Q_{t,3} = A_{t,2} Y_t$$

As it happens, the resulting production is much, much higher than the calculated demand from the cattle sector. A calibration factor of 3.5 is used to align the calculated demand and supply.

Stocks are released for consumption so as to smooth this gradually over the quarters. Prices respond to:

a) if stocks are higher than minimal: $P_t = \left(\frac{Z_{t-1}}{Z^{\text{target}}_{t-1}}\right)^{0.1}$ where the target levels of stocks are specified as the minimum stock plus consumption of 1, 2, 1, and 0 previous quarters for the targets at the end of quarters 2, 3, 4 and 1;

b) $P_t = \left(\frac{Z_{t-1}}{Z^{\text{target}}_{t-1}}\right)^{-0.1}$

In case stocks are projected to reach below half the minimum level, prices adjust so as to induce demand to be reduced stronger and to induce supply in the upcoming season to increase. This demand will equal – approximately – supply by putting price to be

$$P_t = \left(\frac{Z_{t-1}}{Z_{t-1}^{\text{target}}} \right)^{-1.5}$$

The projected level of stocks depends on the predicted demand. This is set to be a demand function

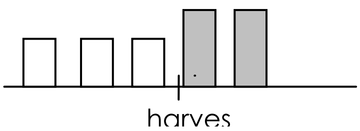
$$D_t^{pred} = D_{t-1}\left(P_{t-1}^{r}\right)^{-0.2}$$

Further considerations as to trade disruptions.

In addition to the possible compulsory culling of cattle, the government should consider the length of the period during which trade is disrupted. A single quarter may not be a problem with sufficient stocks. In case of more quarters, the available stocks must be distributed over the periods until, until what? Until the next harvest if this is large enough, but beyond this harvesting quarter in case the disruption continues.
For a normal exporting country, which has a crop exceeding its consumption, the planned use of the commodity in case of trade disruption need not go beyond the next harvest. If the country is a net importer, the next harvest plays only a contributory role: planning normally goes beyond the (relatively small) crop.

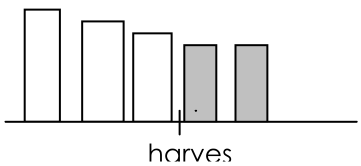
Let demand be relatively steady. At the time of trade disruption, a stock Z_0 is in store. With n=1,2 or 3 periods to go before the next harvest expected to be of size H, how much should typically be released per quarter?
If the planner takes a long view and prepared for equilibrium between production H and demand, the planned release should be in the order of H/4 per quarter and prices should be such that demand adjusts to this. Initially, available stocks per quarter can be larger than H/4 and a gradual transition to the new equilibrium can be accomplished. It is unlikely that this should take long: a quick adjustment to the new situation will be helped by providing the appropriate incentives as soon as possible. We therefore assume that transition will not take longer than until the next harvest, unless there happens to be much more in store by that time than H/4. If that is so, a gradual smoothing is applied until the next harvest.
Thus, we have

If Z/n<H/4: supply in the n quarters until the next harvest is Z/n, after which it becomes H/4



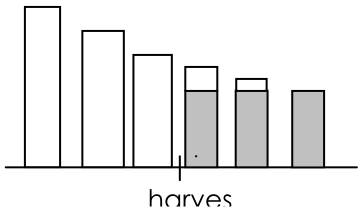
Example of releases for Z/n < H/4, n=3

If Z/n>H/4, a gradual transition to the ‘scarcity’ situation is more appropriate.



Example of releases for Z/n > H/4, n=3

Occasionally, the level of stocks can be so high, or the level of production so low, that large discrepancies would arise between the release out of stock just before harvest, and the new regime after harvest.



Example of releases for Z/n >> H/4, n=3

In this case, part of the stocks can be used to top up the release out of domestic production.
The rationale for gradual transition lies in the beneficial effects of using the feed to complete the optimal growth path of the animals. A sudden disruption of the feed provision would necessitate early discarding of animals and slaughter at less than optimal weight.
Stocks cannot be held forever, and we assume that the transition to a new equilibrium between domestic supply and demand is made within two years.

Complication may arise if, for example, the levels of stocks available are larger than consumption was, and are not needed to facilitate a transition to a new situation.

Simulations with the model are used to select the best policy. The criterion is the development of the prices: the smoother these develop toward a new equilibrium, the less painful the transition.

Outlook as perceived

The above transition to an autarkic situation was made as if the disruption in trade were permanent. In many situations, this may be the most prudent policy but there can also be situations in which trade is disrupted for a specific time, and *known* to return to normality at some point. To accommodate such short-term changes, the provision of feed should be as little disrupted as possible. The target may initially be the next harvesting quarter, on the assumption that trade and production will be normal by then. If production falls short or trade is not restored a further adjustment may be needed.
Typically, for such a short-lived emergency, the levels of stocks that are held at the start of the emergency are important: the larger the stock the better feed provision can be assured.

Prices of products

As supply is forthcoming from the meat and eggs producing sector, prices of the products are determined in the short run by the confrontation of demand and this given supply. This means that prices are a function of the supply:
For a constant-elasticity demand function of the from

$$D = dP^{-\varepsilon}$$

the inverse demand function is

$$P = d^{1/\varepsilon} D^{-1/\varepsilon}$$

For given supply *S=D* this gives the price that equates demand to supply.
Substituting for *d* an expression derived for the base year

$$d = \frac{D_0}{P_0^{-\varepsilon}}$$

the expression for *P* that sets demand equal to supply *S* becomes

$$P = \left(\frac{S}{D_0}\right)^{-1/\varepsilon} P_0$$

In addition to these own-price responses, the demand model includes cross-price effects between the three types of meat that are distinguished (beef, pork and poultry). To accommodate this, we change the above formula, when applied to quarter t, into:

$$P_t = \left(\frac{S_t}{D_0}\right)^{-1/\varepsilon} P_{t-1}^{\varepsilon_j/\varepsilon} P_{t-1}^{\varepsilon_k/\varepsilon}$$

Here ε_j and ε_k refer to the cross-price elasticities of demand with respect to the two other types of meat.

This is applied to the price equations for eggs (ε = 0.15), pork (ε = 0.13), poultry (ε = 0.31) and beef (ε = 0.4), with elasticities equal the FAPRI annual estimates for EU15. Total elasticity matrix is given below, where the cross-price elasticities were taken from Witzke and Zintl.

	pbeef	ppork	ppoultry
Beef	-0.40	0.10	0.01
Pork	0.03	-0.13	0.01
Poultry	0.02	0.06	-0.31

The direct application of these formulas to single quarters (with occasional large changes in supply) leads, however, to great changes in prices from one quarter to the next. This is unlikely, and in practice, product prices are smoothed by changes in stocks of products along the supply chain and with consumers. We therefore look at the change in price that would make demand equal to supply in the longer run. This is accomplished by introducing (a) price lags into the formula: in stead of the formula above we use previous prices (to the power 0.7) and the newly simulated price (to the power 0.3), to give a smoother transition to the new equilibrium; and (b) by using a moving average of production (S_t in the formula) over 4 quarters rather than the previous quarter only.

II.2 Modelling the Animal production systems

The animal production sector in the EU is a large consumer of feedstuff, which makes it a 'competitor' with consumers for grains and oilseeds (part of which currently has to be imported into Europe), while at the same time providing specific food for human consumption. As such, modelling the reaction of the animal production systems to changes in availability / pricing of feedstuff is pivotal in the analysis of effects of trends and calamities on availability and prices of food for the human population in the EU.

In this study, the following animal production systems are modelled each in a separate module, because of their large demands for feedstuff:

- dairy cows
- beef production
- pork production
- chicken production
- egg production

A strong relation exists between the dairy and beef production systems, since many of the animals used for beef production originate from the dairy system. Regarding the pork production system, there is no additional module for the production of the piglets. Instead, feed demands for piglet production are calculated in the pork production system, with a standard feed demand for production of a piglet, accounting for requirements of sows, boars and piglets. The chicken and egg production systems deal in a similar way with the feed demand of the starter chicks.

General set up of the animal production modules

1. In each animal production system, the model keeps track of the number of animals in various age groups and the distribution over age groups. These numbers are variable because during each quarter, animals may:
    - die from natural causes, in which case they are removed from the production system and do not contribute to the production of meat for human consumption; here a difference is made between 'normal' causes and extreme situations during calamities caused by virulent and deadly animal diseases or zoonoses that require massive culling of animals. For the calamity type, it is assumed that also starter animals are directly affected at the start of the quarter, whereas for 'normal' causes the effect is assumed to build up during the quarter.
    - be selectively removed, either at the end of their productive life or because of underperformance during their productive life. Selective removal for underperformance is here only applied to the dairy system;
    - be slaughtered when they reach their optimal weight for slaughtering (meat production systems);
    - or be culled (e.g. because of lack of sufficient feed); these animals are added to the meat production for human consumption;

    At the end of each quarter, the remainder of the animals in each age group is shifted to the next quarter and next age group:

    $$A_q^t = A_{q-1}^{t-1} \cdot \max\left(0, 1 - \delta_d^{t-1} - \delta_c\right) \cdot \left(1 - \max\left(\rho^{t-1}, \chi_{q-1}^{t-1}\right)\right) \cdot \left(1 - \eta_{q-1}^{t-1}\right)$$

    Where

    A_q^t = number of animals of age group t (with 1 = starter) at the start of quarter q

    δ_d^t, δ_c = average fraction of animals of age t dying from natural causes and effects of calamities during the quarter

    ρ^t = average fraction of animals of age t selectively removed during the quarter

    χ_q^t = fraction of animals of age t culled during quarter q because of lack of food

    η_q^t = fraction of animals of age t slaughtered during quarter q (only for meat production systems

2. Each quarter, new starter animals are introduced in the system; the number of these starter animals depends on the number of starters in the quarter before, with an elasticity to quantify the effect of the ratio of prices of the product coming from the production system (e.g. milk) and the feed (assuming an optimum feed quality and specific fractions of soy/oilseeds, grain and roughage). The method to estimate the number of starter animals reflects the differences in set-up of the various production systems:
    - For the broiler production system, with a very short production cycle, it is assumed that setting up new batches of chicken reacts on short notice changes in the ratio of product over feed prices. As such, this ratio of the previous quarter determines to a large extent the amount of animals that will be set-up. However, it is also assumed that the production of

chicks will operate on a more longer term, such that changes in the total amount of chicks that are available in a quarter is restricted to 1.25 times the average number of the preceding four quarters:

$$A_q^1 = \min\left(1.25 \cdot \left(\overline{A}_{q-4:q-1}^1\right),\ A_q^1\left(P_{q-1}\right)^{\varepsilon} \cdot\right) \cdot \left(1-\delta_c\right)$$

$\overline{A}_{q-4:q-1}^1$ = average number of starter animals the 4 quarters preceding quarter q.

P_q = ratio of prices for produce over feed in quarter q.

ε = price elasticity

δ_c = fraction of animals of age t that dies during a calamity caused by epidemics of animal diseases

- For the egg production system, which has a longer production cycle, it is assumed that the change in number of starter layers depends on the average price of the four preceding quarters and, as for broilers, on the average number of starters in the these quarters

$$A_q^1 = \min\left(1.25 \cdot \left(\overline{A}_{q-4:q-1}^1\right),\ A_1^1 \cdot \left(\overline{P}_{q-4:q-1}\right)^{\varepsilon}\right) \cdot \left(1-\delta_c\right)$$

- Setting up new piglets in the pork production system a combination of fast response to prices in the preceding quarter is slowed down by assuming that the response is related to the average number of starters in the four preceding quarters:

$$A_q^1 = \left(\overline{A}_{q-4:q-1}^1\right) \cdot \left(P_{q-1}\right)^{\varepsilon} \cdot \left(1-\delta_c\right)$$

- In the dairy sector model, starters are assumed to replace the animals that died or that were selectively removed (e.g. because of underperformance) in the preceding quarter. When the ratio of product over feed prices is high, more starters may be set-up than is needed for this replacement. However, since the model allows starters to be recruited only from calves produced within the sector, some quarters may see a relative shortage of potential starters, when demand for starters is more than the number of cow-calves that were produced in the preceding quarter. This shortage is accumulated and added to the demand for starter calves in next quarters:

$$A_q^1 = \min\left(A_{q-1}^{cC}, \left(A_{q-1}^{r} + A_{q-1}^{l,r}\right) \cdot \left(\overline{P}_{q-4:q-1}\right)^{\varepsilon}\right) \cdot \left(1-\delta_c\right)$$

Where:

A_{q-1}^{cC} = number of cow calves produced in the preceding quarter

A_{q-1}^{r} = number of animals removed (incl., dead and culled/slaughtered) in the preceding quarter

$A_{q-1}^{l,r}$ = accumulated number of removed animals that were not yet replaced

- The set-up of new animals in the beef production system differs from that in the other systems in the sense that new animals enter not only in the first age group, but also in some of the older age groups. In the model, animals younger than 16 months that are selectively removed from the dairy system enter the beef production system to be fattened to a desired slaughter weight. In addition to animals from the dairy sector, calves are also produced within the beef sector itself. To allow modelling of this internal production of calves, both the number of cow and of bull animals has to be followed:

Bulls (starters only from calves; no older entrants from the dairy sector):

$$A_q^1 = \left(A_{q-1}^{bC,D} + A_{q-1}^{bC},\right) \cdot \left(\overline{P}_{q-4:q-1}\right)^{\varepsilon} \cdot \left(1-\delta_c\right)$$

Cows:

Starter calves:

$$A_q^1 = \left(A_{q-1}^{cC,D} + A_{q-1}^{cC},\right) \cdot \left(\overline{P}_{q-4:q-1}\right)^{\varepsilon} \cdot \left(1-\delta_c\right)$$

Older entrants:

$$A_q^t = A_{q-1}^{t-1} \cdot \max\left(0,1-\delta_d^{t-1}-\delta_c\right) \cdot \left(1-\max\left(\rho^{t-1}, \chi_{q-1}^{t-1}\right)\right) \cdot \left(1-\eta_{q-1}^{t-1}\right) + A_{q-1}^{t-1,D,R}$$

Where:

$A_{q-1}^{bC,D}, A_{q-1}^{bC}$ = bull calves available from the dairy respectively beef sector from the preceding quarter (with cC,D and cC: same for cow calves)

$A_{q-1}^{t-1,D,R}$ = selectively removed animals from the dairy sector

3. During each quarter, the potential demand of the different feed substances (roughage, grain and soybean equivalents) is calculated, assuming an optimal performance of the animals during the quarter, and assuming that on average animals that die from natural causes do this halfway during the quarter, (therefore requiring half the feed) while selection of animals to remove is done at the end of the quarter (and therefore requiring full feed):

$$D_q^{f,p} = \sum_{t=1}^{n}\left(A_q^t \cdot \max\left(0,1-0.5\cdot\delta_d^t-\delta_c\right) \cdot U_o^{f,t}\right)$$

Where:

$D_q^{f,p}$ = total demand for feed stuff of type f during quarter q for animals of all age groups present in that quarter

$U_o^{f,t}$ = optimal use of feed stuff (concentrate, roughage) of type f per quarter for each animal of age t (parameter, depending on scenario regarding efficiency of animal production)

4. For systems where roughage is used, the use for roughage is related to the potential demand, multiplied by the effect of the relative price of roughage:

$$U_q^r = D_q^{r,p} \cdot \left(\pi_{q-1}^r\right)^{\varepsilon}$$

with

π_{q-1}^r = relative price of roughage in the preceding quarter

ε = price elasticity for use of roughage (set at -0.1)

5. From the potential demand of concentrate, the required amount of protein coming from concentrate (c) is calculated:

$$P_q^c = D_q^{c,p} \cdot (S_o^c \cdot P^s + G_o^c \cdot P^g)$$

Where:

P_q^c = Protein demand from concentrate in quarter q

S_o^c, G_o^c = Optimum fraction of soybean and grain equivalents in concentrate

P^s, P^g = fraction of protein in soybean and grain equivalents

6. Depending on the ratio of the prices for protein from soybean and from grain, the required amounts of soybean and grain to supply the protein are chosen:

$$D_q^s = \max(0.,\min(1.,\Pi_q)) \cdot S_o^c \cdot D_q^{c,p}$$

$$D_q^g = (P_q^c - D_q^s \cdot P^s) / P^g$$

Where:

D_q^s, D_q^g = total demand for soybean and grain, respectively, in quarter q

$\Pi_q = \left(\frac{P^s}{\pi_q^s}\right) / \left(\frac{P^g}{\pi_q^g}\right)$ = price of protein from soybean relative to that from grain in quarter q

π_q^s , π_q^g = relative price of soybean and grain respectively. Under 'normal' conditions, these prices are the average over the 4 preceding quarters while under conditions with trade limitations these prices are those of the last preceding quarter. This reflects the change in expectations of producers when normal price setting mechanisms are not valid any more. Since the protein content of soybean is about 3 times higher than that of grains, switching to grains will only occur when soybean prices are more than 3 times higher per unit dry matter than those of grains (Figure 30).

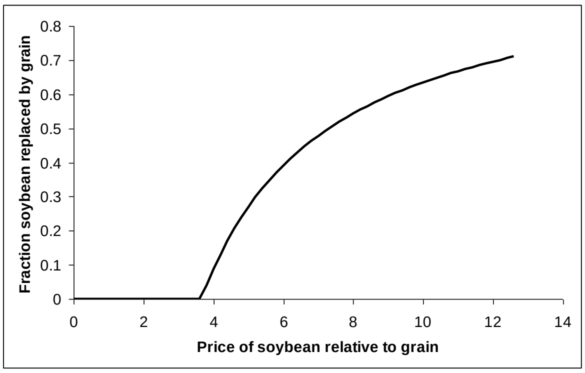


Figure 30 Effect of the price of soybean relative to that of grains on the substitution of soybean by grain in animal feed. Substitution is expressed in the fraction of soybean in an optimal diet at zero price of soybean.

7. Apart from soybean and grain, concentrate contains also other substances. Here it is assumed that these additives serve other purposes than to supply energy or protein, and that the amount of these additives is independent of the soy-grain ratio. The demand for additives is then calculated by

$$D_q^a = D_q^{c,p} \cdot (1 - S_o^c - G_o^c)$$

8. The resulting real demand for concentrate in each quarter then equals the sum of the demands for grain, soybean and additives:

$$D_q^c = D_q^g + D_q^s + D_q^a$$

9. The use of concentrate with the resulting soy-grain-additive content is made dependent on the relative price of the concentrate, where it is assumed that the relative price for additives equals that for grains:

$$U_q^c = D_q^c \cdot \left(\frac{\left[\left(\frac{D_q^g + D_q^a}{D_q^c} \right) \cdot \pi_q^g + \left(\frac{D_q^s}{D_q^c} \right) \cdot \pi_q^s \right]}{\pi_q^m} \right)^{\varepsilon}$$

With

ε = price elasticity, being the weighted average of the elasticities for grain and soy:

$$\varepsilon = \left(\frac{D_q^g + D_q^a}{D_q^c} \right) \cdot \varepsilon^g + \left(\frac{D_q^s}{D_q^c} \right) \cdot \varepsilon^s$$

In case of a minimum requirement of roughage as fraction of total intake, e.g. to prevent problems in the digestion system in high productive dairy cows, the available amount of roughage determines the maximum amount of concentrate that can be used:

$$U_q^c = \min\left(U_q^c, \frac{(1-\alpha)}{\alpha} \cdot U_q^r\right)$$

Where

α = minimal fraction of roughage in the diet

10. The intake of food is translated into production, i.e. meat, milk, eggs.
Meat is expressed in average carcass weight after slaughtering, which is assumed to be an age specific fraction of the live weight that varies between bovines, pigs and chicken.
For all meat producing systems (including dairy), an optimal growth of live weight of animals is assumed to exist (Figure 31 for dairy, beef and pork production). In the case of dairy, it is assumed that animals indeed follow this curve and that only the production of milk is affected by quantity and quality of feed. In the other meat production systems, the growth of live weight will follow this curve when optimal quantity and quality of feed is provided, but will be reduced when less quality and/or less quantity is available.

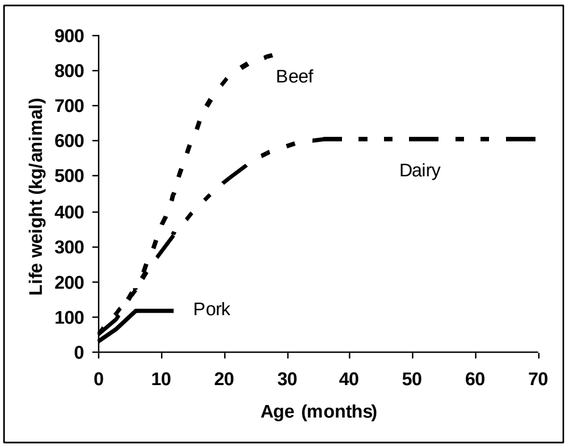


Figure 31 Relation of optimal weight of fattening pigs, dairy and beef cattle to their age as used in the model

Per quarter, the optimal growth in life weight (G_q^o) over the whole population of animals is calculated as the sum of the optimal growth per age group:

$$G_q^o = \sum_{t=1}^{n} G_q^t$$

$$G_q^{t,o} = A_q^t \cdot \left(W_o^t - W_o^{t-1}\right) \cdot \max\left(0, 1 - \delta_d^t\right) \cdot \max\left(0, 1 - \delta_c\right)$$

for animals remaining till the end of the quarter

$$G_q^{t,o} = A_q^t \cdot \left(W_o^t - W_o^{t-1}\right) \cdot \min\left(1, 0.5 \cdot \delta_d^t\right) \cdot \max\left(0, 1 - \delta_c\right)$$

for animals dying from natural causes during the quarter

With

W_o^t = optimal end weight for age group t

From the protein content of the total feed for all animals (except dairy cattle), the actual feed conversion rate for all animals is calculated according to

$$FC_q = \left(PC_q^t - PC_{\min}\right) \cdot \frac{\left(FC_{\max} - FC_{\min}\right)}{\left(PC_{\max} - PC_{\min}\right)} + FC_{\min}$$

Where

FC = Feed Conversion rate (kg life weight gain / kg dry weight feed consumed)
PC = protein content (kg protein / kg dry weight feed)

To take the quantity of feed into account, the actual growth as fraction of optimal growth (FG) is quantified by

$$FG_q = \left(\frac{U_q^c + U_q^r}{G_q^o} \right)$$

Finally, the actual growth rate in life weight is calculated as the optimal growth multiplied by the fraction of growth that is achieved:

$$G_q^{t,a} = FG_q \cdot G_q^{t,o}$$

In the dairy system, milk production is related to the uptake of roughage and concentrate, where the feed quality determines the feed conversion:

$$FC_q = FC_q^o \cdot \left(0.7 + \frac{0.3}{fR^2} \cdot \left(\frac{U_q^r}{U_q^r + U_q^c} \right) \cdot (2 \cdot f\,R - \left(\frac{U_q^r}{U_q^r + U_q^c} \right) \right)$$

Where

fR = optimal fraction of roughage in diet

FC_q^o = maximal conversion of feed into milk

Both fR and FC_q^o vary according to the animal production scenario.

Thus, an optimum curve of Feed Conversion versus fraction roughage is introduced into the model (Figure 32)

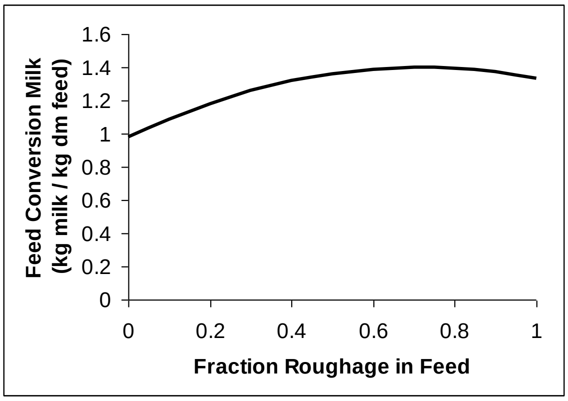


Figure 32 Relation between conversion of feed into milk in relation to fraction roughage as used in the model, for maximal conversion of feed into milk of 1.4 litre milk per kg dm feed, and optimum fraction roughage of 0.72.

The total milk production is then calculated by multiplying the Feed Conversion with the total amount of feed consumed by cows of 9 months and older.

The optimal amount of feed for dairy is calculated by dividing the average potential milk production per cow per year by the maximum Feed Conversion; the optimal amount of roughage is then determined by multiplying the total feed by the optimal roughage fraction, with the optimal amount of concentrate as remainder. Implicitly, this calculation assumes an optimal composition of concentrate, which in the module is described by the fraction of grain products, of soybean products and of other material.

In the egg production module, it is assumed that under optimal diet, chicken produce a maximum number of eggs per year, depending on their age. When the quality of the diet, expressed in protein content, becomes less than optimal, egg production is reduced:

$$E_q^t = FQ_q \cdot \left(A_q^{t,l} - 0.5 \cdot A_q^{t,d} \right) \cdot \left(\frac{90}{365} \right) \cdot EP^t$$

$$E_q = \sum_{t=1}^{n} E_q^t$$

Where:

E_q^t, E_q = egg production in quarter q, per cohort of chicken in age group t and total over all age groups respectively.

FQ_q = feed quality in quarter q

$A_q^{t,l}$, $A_q^{t,d}$ = number of chicken of age t to survive (l) or die from natural causes (d) in quarter q

EP^t = Optimal yearly egg production per chicken of age t

90, 365: = number of days in quarter and in year respectively

11. Production of starter animals (calves, piglets, chicks)
    In the pork, broiler and egg production systems, the potential amount of starter animals is assumed not to be limiting. In the beef production system, calves that are not needed in the dairy system form one part of the potential starters. This is a limited supply and is determined by the dynamics in the dairy production system. Another source of starters is formed by the calves produced within the beef production system, which here is assumed to respond to the price ratio

    In the dairy and beef modules, production of calves is explicitly included, since the amount of available cow calves can limit the expansion of the sector. The availability of bull calves and unneeded cow calves from the dairy sector generally is an important input to the beef module.

    The model assumes that different age groups (heifers, cows between 3 and 7 years and 'senior'cows above 7 years old) have different calving rates, while there is also some seasonality in calving. In addition, the model takes into account that not all calves are born alive, and that the fraction cow calves may be different from 0.5:

$$C_q = FL \cdot CS_q \cdot \sum_{t=1}^{n} \left\{ \left(A_q^{t,l} - 0.5 \cdot A_q^{t,d} \right) \cdot CR^t \right\}$$

$$C_q^c = FC \cdot C_q$$

$$C_q^b = C_q - C_q^c$$

Where

FL , FC = fraction live born calves and cow calves respectively

CS_q = fraction of calves being born in quarter q, relative to total yearly born calves

$C_q \cdot C_q^c \cdot C_q^b$ = calves born in quarter q: total, cows (*c*) and bulls (*b*) respectively

$A_q^{t,l}, A_q^{t,d}$ = total number of cows surviving (*l*) and dying of natural causes (*d*), respectively, of age group t in quarter q

CR^t = average number of calves produced per cow of age group t

Animals selectively removed from the dairy sector (see next paragraph) contribute to the production of beef. Animals younger than 7 months enter the beef sector for further fattening, while older animals are slaughtered directly.

12. Selective removal of animals
    In the beef, pork, broiler and egg production systems, it is assumed that selective removal of animals, e.g. because of underperformance, is included in the mortality rate. It is also assumed that such selective removal is not affected by the ratio of prices of produce and feed.

    In the dairy system, selective removal takes place over the whole range of animals (see item 1 in this section, where ρ^t expresses the selective removal rate), where fraction of animals being removed depends on the age group (Figure 33).

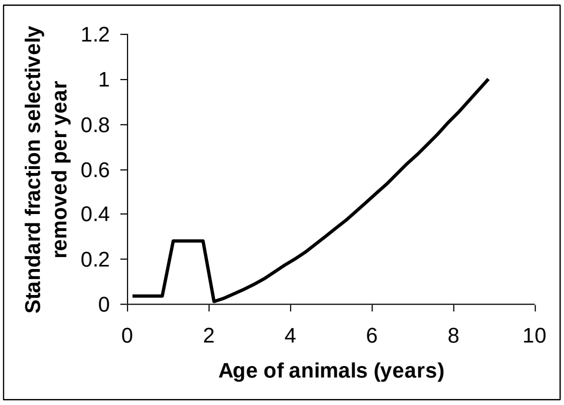


Figure 33 Standard fraction of animals selectively removed yearly in dependence of age of the animals

In addition, selection of animals is affected by the ratio of prices of milk over feed, such that at higher ratios, less animals are removed (Figure 34):

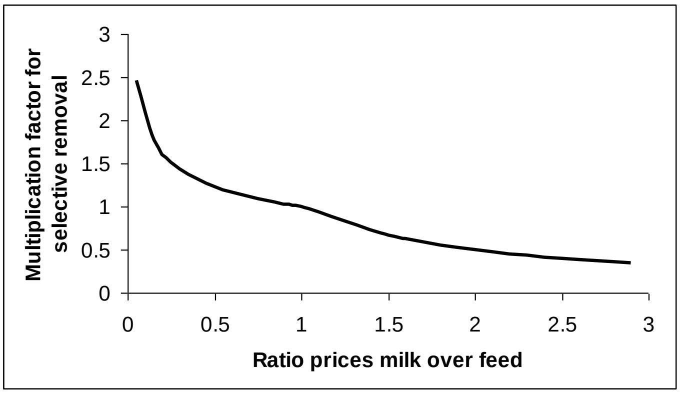


Figure 34 Effect of the milk/feed price ratio on selective removal of animals from the dairy sector, expressed as a multiplication factor on the standard removal rate.

13. Culling because of food shortage
When not enough feed is available, the model assumes that in the meat production systems, growth of the animals will be slower, leading to a delay in reaching the slaughtered weight.
In the dairy and egg production systems, some of the animals will be culled to allow the remaining animals sufficient access to feed to produce at close as possible as under optimal conditions. Animals that will be culled first are the less productive animals, which in the model is related to the age group.

Table 25 Order of culling of animals in case of shortage of feed

Production system	Culling group		
	1	2	3
Dairy	Cows > 8 years	Calves & heifers <= 2 years	Cows >2 and <8 years
Eggs	Chicken > 12 months	Chicken <4 and > 9 months	Chicken >4 and < 9 months

In the dairy system, it is assumed that culling starts when a particular culling group has too little roughage available:

$$AR_q^{cg} = \min\left(RR_q^{cg}\, RR_q^{tot} - \sum_{cr=cg+1}^{3} RR_q^{cr}\right)$$

$$FC_q^{cg} = \min\left(1, \max(0., 1 - \frac{AR_q^{cg}}{\alpha \cdot RR_q^{cg}}\right)$$

with

AR_q^{cg}, RR_q^{cg} = available and required roughage respectively per quarter for culling group cg, with cr = later culling groups and tot = total over all culling groups

FC_q^{cg} = fraction of culled animals during quarter q in culling group cg

α = fraction of required roughage (which includes requirement for milk production) before culling actually will start; in the model assumed to be 0.75.