10.2. Human consumption

Jörg Rieger
Thünen Institute

Scenarios for changes in food consumption become more important

- Recent CAPRI studies:

Global Food Security 28 (2021) 100437

Contents lists available at ScienceDirect

Global Food Security

journal homepage: www.elsevier.com/locate/gfs

ELSEVIER

Paying the price for environmentally sustainable and healthy EU diets

Catharina Latka[a,*], Marijke Kuiper[b], Stefan Frank[c], Thomas Heckelei[a], Petr Havlík[c], Heinz-Peter Witzke[a], Adrian Leip[d], Hao David Cui[b], Anneleen Kuijsten[e,f], Johanna M. Geleijnse[e,f], Michiel van Dijk[b,c]

nature communications

Article

https://doi.org/10.1038/s41467-023-41789-3

The global and regional air quality impacts of dietary change

Received: 8 March 2022

Accepted: 18 September 2023

Marco Springmann[1,2], Rita Van Dingenen[3], Toon Vandyck[4,5], Catharina Latka[6], Peter Witzke[6,7] & Adrian Leip[8]

Received: 4 July 2022 | Revised: 29 November 2022 | Accepted: 19 January 2023

DOI: 10.1111/1477-9552.12530

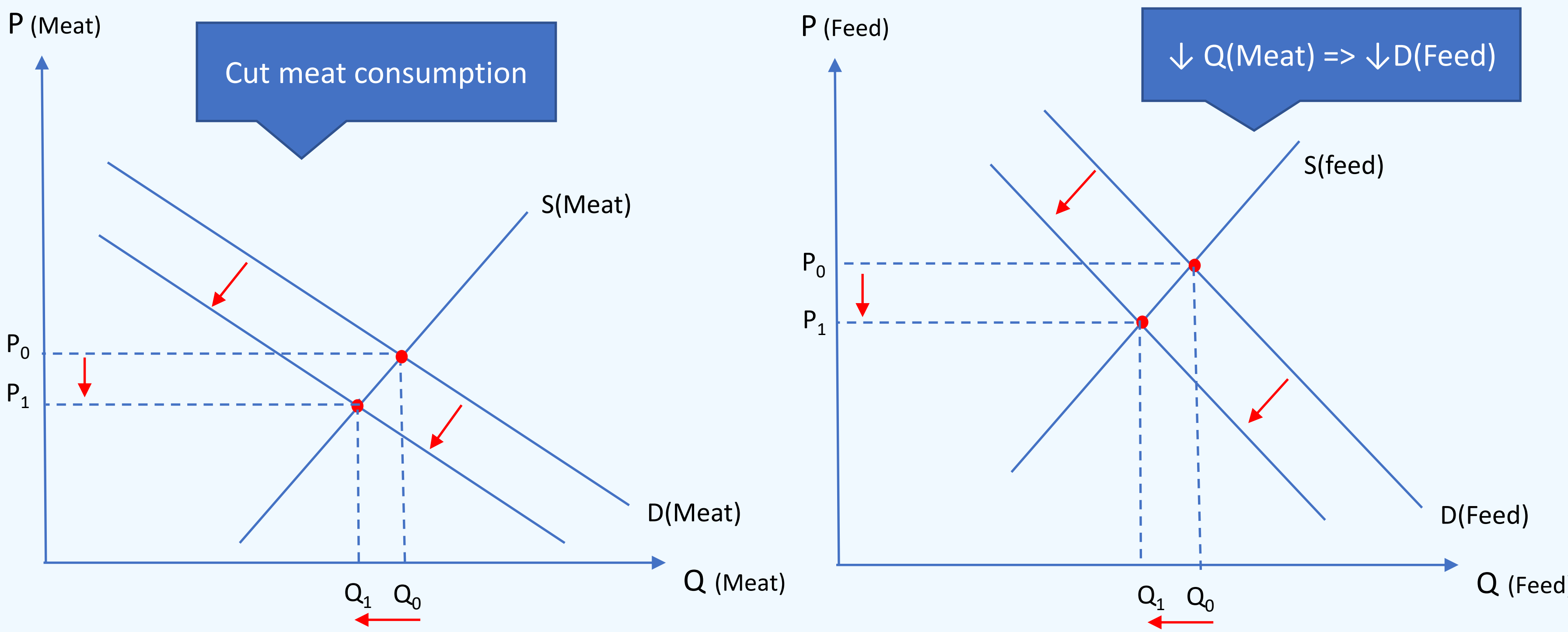
ORIGINAL ARTICLE

JAE Journal of Agricultural Economics

From fork to farm: Impacts of more sustainable diets in the EU-27 on the agricultural sector

Jörg Rieger[1] | Florian Freund[2] | Frank Offermann[1] | Inna Geibel[2] | Alexander Gocht[1]

Theoretical Background: Shock Human consumption



Human consumption in CAPRI

Generalized Leontief Expenditure System

$$F = \sum_i D_i \; P_i$$

$$G = \sum_i \sum_j B_{i,j} \sqrt{P_i \; P_j}$$

Differentiate w.r.t. P_i …

$$\frac{\partial F}{\partial P_i} = F_i = D_i$$

$$\frac{\partial G}{\partial P_i} = G_i = \sum_j B_{i,j} \sqrt{P_j / P_i}$$

Expenditure remaining after commitments are covered

$$\Rightarrow x_i = \left[D_i + \frac{G_i}{G} (Y - F) \right] Pop$$

Value of minimum commitments

D_i = Consumption independent of prices and income

Human consumption in CAPRI

"\gams\arm\market_model.gms"

```
* --------------- Behavioural functions
*$onlisting
*
* --- definition of F as sum of Di multiplied with prices for the Generalised Leontief expenditure funtion
*                     PD: commitments / linear terms in the individual demand functions
*                     (in kg per capita, therefore prices are expressed in Euro/kg <=> CPRI [Euro/ton] * 0.001)
*
 GLDemandFS_(RMS) $ sum(xxx $ v_consQuant.range(RMS,XXX),1) ..
*
     v_GLDemandFS(RMS) /
*
*          --- the following term (also found o the RHS) is only for scaling purposes
*              to bring the equation around unity
*
          (SUM(XX1 $ p_pdGL(RMS,XX1,"CUR"),
                       DATA(RMS,"CPRI",XX1,"CUR") * p_pdGL(RMS,XX1,"CUR")*1.E-3) + 0.1)

      =E= SUM(XX1 $ p_pdGl(RMS,XX1,"CUR"),
                       v_consPrice(RMS,XX1) * p_pdGL(RMS,XX1,"CUR")*1.E-3)
        / (SUM(XX1 $ p_pdGL(RMS,XX1,"CUR"),
                       DATA(RMS,"CPRI",XX1,"CUR") * p_pdGL(RMS,XX1,"CUR")*1.E-3) + 0.1);
.
*
* --- definition of function G for the Generalised Leontief expenditure funtion
*      (per capita)
*
 GLDemandGS_(RMS) $ sum(xxx $ v_consQuant.range(RMS,XXX),1) ..
*
*    --- due to DF in the calibration of the parameter set, it is possible
*        to fix v_GLDemandGS durign a value. That value is 10000. and
*        use in the equation for scaling to bring the equation to unity in the
*        calibration point
*
     v_GLDemandGS(RMS)/10000. =E= SUM( (XX1,YY1) $ p_pbGL(RMS,XX1,YY1,"CUR"),
                                 p_pbGL(RMS,XX1,YY1,"CUR")
                                   * SQRT(v_consPrice(RMS,XX1)*v_consPrice(RMS,YY1)*1.E-6) )/10000.;
```

$$F = \sum_i D_i \; P_i$$

D_i = Consumption independent of prices and income

$$G = \sum_i \sum_j B_{i,j} \sqrt{P_i \; P_j}$$

Human consumption in CAPRI

"\gams\arm\market_model.gms"

```
* --- definition of first derivatives of G called Gi for the Generalised Leontief expenditure funtion
*       (per capita)
*
 GLDemandGis_(RMS,XXX) $ (  (v_consQuant.LO(RMS,XXX) ne v_consQuant.UP(RMS,XXX))
                            $ DATA(RMS,"HCon",XXX,"CUR"))   ..

     v_GLDemandGis(RMS,XXX)

*                 --- the following is only a scaling term to bring the equation around unity
*                     in  calibration point. It is also found on the RHS
*
                  /    (SUM( YY1 $ p_pbGl(RMS,XXX,YY1,"CUR"),
                                   p_pbGL(RMS,XXX,YY1,"CUR")
                                     * SQRT(DATA(RMS,"CPRI",YY1,"CUR")/DATA(RMS,"CPRI",XXX,"CUR"))) + 0.1)

                  =E= [SUM( YY1 $ p_pbGl(RMS,XXX,YY1,"CUR"),
                                     p_pbGL(RMS,XXX,YY1,"CUR")
*
*                                    ---- the division / multiplication by DATA(RMS,"CPRI",XXX,"CUR")
*                                         cancel out and are only introduced to stabilize
*                                         the numerical solution
*
                                     * SQRT(v_consPrice(RMS,YY1)/DATA(RMS,"CPRI",XXX,"CUR")))
                                     * SQRT(DATA(RMS,"CPRI",XXX,"CUR")/v_consPrice(RMS,XXX))
                       ]
*
                  /    (SUM( YY1 $ p_pbGl(RMS,XXX,YY1,"CUR"),
                                   p_pbGL(RMS,XXX,YY1,"CUR")
                                     * SQRT(DATA(RMS,"CPRI",YY1,"CUR")/DATA(RMS,"CPRI",XXX,"CUR"))) + 0.1);
```

$$G = \sum_i \sum_j B_{i,j} \sqrt{P_i \; P_j}$$

Differentiate w.r.t. P_i ...

$$\frac{\partial G}{\partial P_i} = G_i = \sum_j B_{i,j} \sqrt{P_j / P_i}$$

Human consumption in CAPRI

"\gams\arm\market_model.gms"

```
* ----- definition of human consumption for the Generalised Leontief expenditure funtion
*
 XiS_(RMS,XXX)  $ (  (v_consQuant.LO(RMS,XXX) ne v_consQuant.UP(RMS,XXX))
                    $ DATA(RMS,"HCon",XXX,"CUR")) ..
*
     (  v_consQuant(RMS,XXX)     $ ( v_consQuant.LO(RMS,XXX) GT 0)
      + v_consQuantNeg(RMS,XXX) $ ( v_consQuant.LO(RMS,XXX) LE 0)
     )
     /(DATA(RMS,"HCon",XXX,"CUR")+0.1) =E=
*
       ((v_GLDemandGis(RMS,XXX)/v_GLDemandGS(RMS)
           * ( DATA(RMS,"Ince","Levl","CUR")/DATA(RMS,"INHA","LEVL","CUR") - v_GLDemandFS(RMS))
              + p_pdGL(RMS,XXX,"CUR")) * DATA(RMS,"INHA","LEVL","CUR")/1000.)/(DATA(RMS,"HCon",XXX,"CUR")+0.1);
```

$$\Rightarrow x_i = \left[D_i + \frac{G_i}{G}(Y - F)\right] Pop$$

Value of minimum commitments

D_i = Consumption independent of prices and income

Diet shifts in CAPRI

Implementation of diet shifts in CAPRI model

(e.g. 10% decrease in demand for beef)

- GL demand function shifted under constant price assumption
  - ➢ New demand curve through 10% less demand for beef at the same price

- Demand curve is shifted by adjusting the commitment terms („**p_pdGL**“)
  - ➢ Recalibration of commitment terms to match new demand at original price
  - ➢ Analogous to shifting the constant term in linear demand functions

$$PerCap_i = D_i + \frac{G_i}{G}(y - F); Di = p\_pdGL$$

Diet shifts in CAPRI

```
   set scenshiftedCols(COLS) / UVAG
$IF %MARKET_M%==ON           TCost
$IF %MARKET_M%==ON           HCON
$IF %MARKET_M%==ON           FEED
$IF %MARKET_M%==ON           PROD
$IF %MARKET_M%==ON           PROC ,
$IF %MARKET_M%==ON           SET.bioScenShifted
$IF %MARKET_M%==ON           SET.foreOlndArtif
$IF %MARKET_M%==ON           LEVL
```

```
$IFI %MARKET_M%==ON SET ScenItems(COLS) "Items which can be trend shifted via scendefinition" / set.scenshiftedCols /;
```

```
DATA(RMS,"HCON","beef","PercentageChange") = -10;
```

arm\prep_market.gms

```
*
*  --- shift human consumption, feed, processing, production according to exogenously defined
*      (using XX1 permits to pick up shifters for PROD.LAND = land area for non-supply model
*
 DATA(RMS,ScenItems,XX1,"CUR")  $ DATA(RMS,ScenItems,XX1,"AbsoluteLevel")
     = DATA(RMS,ScenItems,XX1,"AbsoluteLevel");
*
 DATA(RMS,ScenItems,XX1,"CUR")  $ DATA(RMS,ScenItems,XX1,"AbsoluteChange")
    = DATA(RMS,ScenItems,XX1,"CUR") + DATA(RMS,ScenItems,XX1,"AbsoluteChange");
*
 DATA(RMS,ScenItems,XX1,"CUR")  $ DATA(RMS,ScenItems,XX1,"ChangeFactor")
      = DATA(RMS,ScenItems,XX1,"CUR") * DATA(RMS,ScenItems,XX1,"ChangeFactor");
*
 DATA(RMS,ScenItems,XX1,"CUR")  $ DATA(RMS,ScenItems,XX1,"PercentageChange")
  = DATA(RMS,ScenItems,XX1,"CUR") * (1. + DATA(RMS,ScenItems,XX1,"PercentageChange")/100);
```

```
v_consQuant.L(RMS,XX)   = DATA(RMS,"HCon",XX,"CUR");
```

Diet shifts in CAPRI

```
\gams\arm\trim_gl_commits.gms
```

```
GAMS file : TRIM_GL_COMMITS.GMS

@purpose  : Recalibrate commitments of Generalized Leontief Demand
            System to given prices and quantities by miminmizing
            differences to given commitments
```

```
EQUATIONS trimGLCommits1_  "Value of commitments"
          trimGLCommits2_  "Demand equation"
          trimGLCommits3_  "Definition of squared differences between given and calibrated commitments";

VARIABLES v_commitPar(RMS,XX1)  "Commitment parameter of Generalized Leontief Demand System"
          v_Obje                "Objective function";
*
trimGLCommits1_(RMS) ..
*
    v_GLDemandFS(RMS)  =E= SUM(XX1 $ ((DATA(RMS,"Hcon",XX1,"CUR") or SAMEAS(XX1,"INPE")) and p_pdGL(RMS,XX1,"CUR")),
                              v_consPrice.L(RMS,XX1) * v_commitPar(RMS,XX1)*1.E-3);

trimGLCommits2_(RMS,XX) $ (DATA(RMS,"Hcon",XX,"CUR") and v_GLDemandGis.l(RMS,XX) and p_pdGL(RMS,XX,"CUR")) ..

    v_consQuant.L(RMS,XX)  =E=  (v_GLDemandGIs.L(RMS,XX)/v_GLDemandGs.L(RMS)
                              * ( DATA(RMS,"Ince","Levl","CUR")/DATA(RMS,"INHA","LEVL","CUR")
                                - v_GLDemandFS(RMS)) + v_commitPar(RMS,XX))
                                           * DATA(RMS,"INHA","LEVL","CUR")/1000.;
*
trimGLCommits3_ .. v_Obje =E= SUM( (RMS,XX1) $ (v_GLDemandGis.l(RMS,XX1) and p_pdGL(RMS,XX1,"CUR")),
                                 SQR(v_commitPar(RMS,XX1) - P_pdGL(RMS,XX1,"CUR")));

MODEL  m_trimGLCommits "Model to calibrate commitments of GL demand system to given prices and quantities"
     / trimGLCommits1_,trimGLCommits2_,trimGLCommits3_ /;
*
```

$$x_i = [D_i + \frac{G_i}{G}(y - F)]^{*}Pop$$

Diet shifts in CAPRI

```
\gams\arm\recalibrate_commitments.gms
```

```
@purpose  : Redefine commitments terms of Generalized Leontief demand
            System to match given quantities and prices
```

```
m_trimGLCommits.Solprint  = 1;
m_trimGLCommits.iterlim   = 10000;
m_trimGLCommits.Solvelink = 5;
SOLVE m_trimGLCommits USING NLP Minimizing v_obje;
if ( EXECERROR > 0, abort "internal error");


if(m_trimGLCommits.numinfes > 0,
 execute_unload "%resdir%\chk_p_pdGL.gdx";
 abort "m_trimGLCommits.numinfes > 0 ", m_trimGLCommits.numinfes;
 );

p_pdGL(RMS,XX1,"CUR") = v_commitPar.L(RMS,XX1);
```

Diet shifts in CAPRI

Consumption-Related Indicators in CAPRI

HCON = Food intake + market losses (**LOSM**) + industrial use (**INDM**) + consumption-stage losses (**LOSC**)

HCOM = Food intake + consumption-stage losses (**LOSC**)

N_CAL = Food intake (kcal per capita and day)

N_PRO = Food intake (g proteins per capita and day)

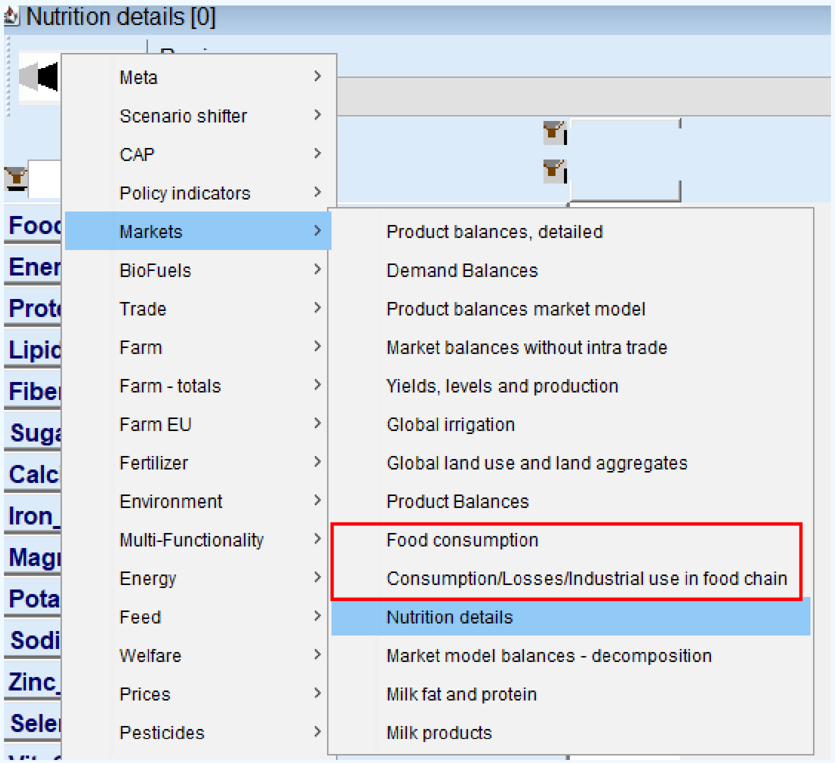
N_FAT = Food intake (g fat per capita and day)

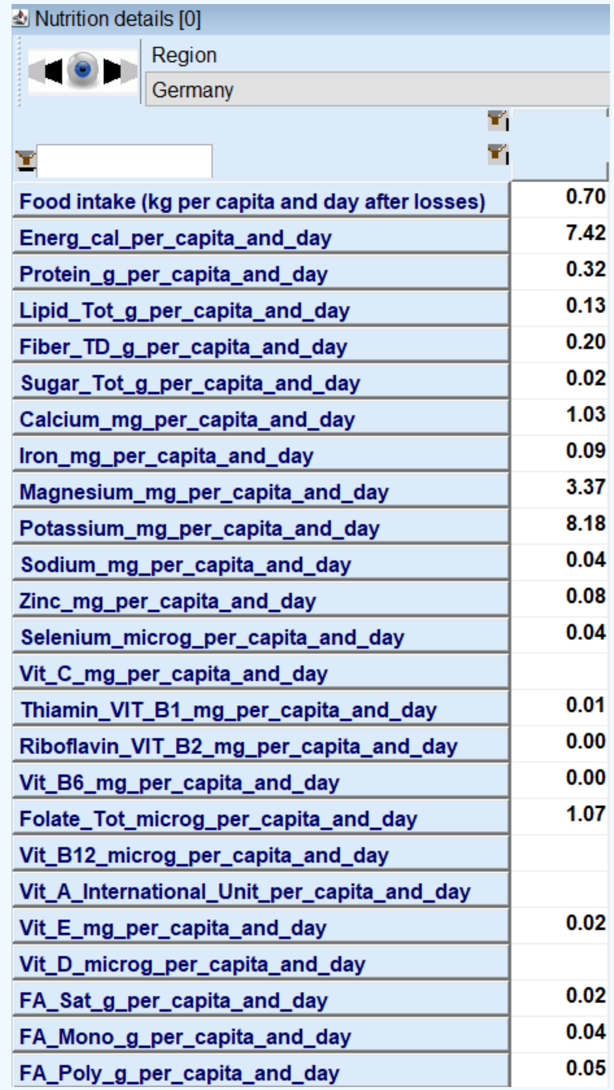
………

INHA = Food intake (kg per capita and year)

- *dataOut(DE000000, ”” , INHA , BEEF , 2030)*

Diet shifts in CAPRI




Nutrition details [0]

Region: Germany

Food intake (kg per capita and day after losses)	0.70
Energ_cal_per_capita_and_day	7.42
Protein_g_per_capita_and_day	0.32
Lipid_Tot_g_per_capita_and_day	0.13
Fiber_TD_g_per_capita_and_day	0.20
Sugar_Tot_g_per_capita_and_day	0.02
Calcium_mg_per_capita_and_day	1.03
Iron_mg_per_capita_and_day	0.09
Magnesium_mg_per_capita_and_day	3.37
Potassium_mg_per_capita_and_day	8.18
Sodium_mg_per_capita_and_day	0.04
Zinc_mg_per_capita_and_day	0.08
Selenium_microg_per_capita_and_day	0.04
Vit_C_mg_per_capita_and_day	
Thiamin_VIT_B1_mg_per_capita_and_day	0.01
Riboflavin_VIT_B2_mg_per_capita_and_day	0.00
Vit_B6_mg_per_capita_and_day	0.00
Folate_Tot_microg_per_capita_and_day	1.07
Vit_B12_microg_per_capita_and_day	
Vit_A_International_Unit_per_capita_and_day	
Vit_E_mg_per_capita_and_day	0.02
Vit_D_microg_per_capita_and_day	
FA_Sat_g_per_capita_and_day	0.02
FA_Mono_g_per_capita_and_day	0.04
FA_Poly_g_per_capita_and_day	0.05

CAPRI-Scenario: Reduced meat consumption

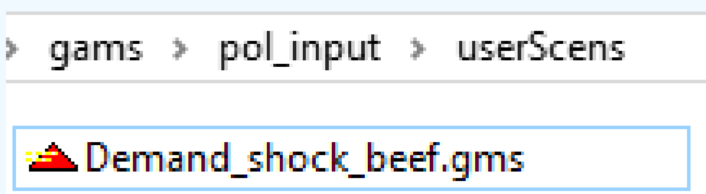
Decrease in meat-based calorie consumption above a given threshold (minimum requirements in kcal for healthy diets)

- Threshold levels according to recommendations by Lancet Commission on healthy diets based on a diet of 2500 kcal per day
  - Calorie intake from animal products: 340 kcal/capita/day
  - Calorie intake from meat: 128 kcal/capita/day
  - **Calorie intake from beef: 7.5 kcal/capita/day**
- Reduction of meat consumption above some threshold level ("luxury consumption") for the daily calorie requirements (kcal/day/capita)
- Partial compensation of reduced calorie intake from meat products e.g. 50% of the cut in meat calories with vegetables, fruits and legumes
  - Consideration of increasing preferences for vegetarian products

CAPRI-Scenario „Demand_shock_beef.gms“

- Reduction of beef consumption above some threshold level (“luxury consumption”) by 30% in the EU

- Compensation of reduced calorie intake from beef with vegetables, fruits and legumes by 50% in the EU



CAPRI-Scenario „Demand_shock_beef.gms“

```
set X_T_foodagg(rows,foodagg)
      /(BEEF).beef
       (PULS,SOYA,TOMA,OVEG,APPL,OFRU,CITR,TAGR).leguveg
      /;
```

```
* ------------------------------------------------------------------------------
* Parameter p_dietChange to define reference diets and dietary shifts
* ------------------------------------------------------------------------------
parameter p_dietChange(EU27_Brexit,*,*,*) "parameter to define diet change scenarios" ;

 execute_load "%results_in%\capmod\res_2_%BAS%%SIM%cap_after_2014_ref%reg_agg%.gdx" p_DataOutTemp=dataout;

* --- calories by food group in the reference scenario

  p_dietChange(EU27_Brexit,"calories_ref",foodagg,"%SIMY%")
     = sum(X_T_foodagg(rows,foodagg), p_DataOutTemp(EU27_Brexit,"","n_cal",rows,"%SIMY%"));
```

```
*Define the products for which the consumer demand will be reduced (e.g. redmeat or allmeat)
$setglobal cutmeat    beef
*Define the Cut in calories intake from meat in (% decrease in calories intake above threshold)
$setglobal cutrate_meat   30

*Define substution products for reduced calorie intake from meat (e.g. legumes or leguveg)
$setglobal subst_veg  leguveg
* Define the rate of substitution (% compensation of the reduced meat calories )
$setglobal subst_rate_veg  50
```

```
parameter p_cutCons(rows,simyy) "relative cut for excess meat-based calorie consumption";
  p_cutCons("%cutmeat%","%SIMY%") = %cutrate_meat%/100;
```

```
parameter p_cutCons_v(rows,simyy) "substitution of relative cut for excess meat-based calorie consumption with vegetables and fruits";
 p_cutCons_v("%subst_veg%","%SIMY%") = %subst_rate_veg%/100;
```

CAPRI-Scenario „Demand_shock_beef.gms“

```
parameter p_threshCAL(rows)
    /beef      7.5/;
```

Lancet recommendations (kcal per capita and day)

```
* --- meat calories after cut (but before endogenous adjustments in simulation) reduction on meat-based calories only above threshold level

 p_dietChange(EU27_Brexit,"calories_sim","%cutmeat%","%SIMY%")
    = p_dietChange(EU27_Brexit,"calories_ref","%cutmeat%","%SIMY%")
      - max(0,min(p_dietChange(EU27_Brexit,"calories_ref","animpro","%SIMY%")-p_threshCAL("animpro"),
                  p_cutCons("%cutmeat%","%SIMY%")*(p_dietChange(EU27_Brexit,"calories_ref","%cutmeat%","%SIMY%")-p_threshCAL("%cutmeat%")))
             );
```

```
* --- define relative cut for meat

 p_dietChange(EU27_Brexit,"PercentageChange","%cutmeat%","%SIMY%") $ p_dietChange(EU27_Brexit,"calories_ref","%cutmeat%","%SIMY%")
    = (p_dietChange(EU27_Brexit,"calories_sim","%cutmeat%","%SIMY%")/p_dietChange(EU27_Brexit,"calories_ref","%cutmeat%","%SIMY%")-1)*100;

* --- define relative shift in meat consumption

 DATA(EU27_Brexit,"HCON","%cutmeat%","PercentageChange") = p_dietChange(EU27_Brexit,"PercentageChange","%cutmeat%","%SIMY%");
```

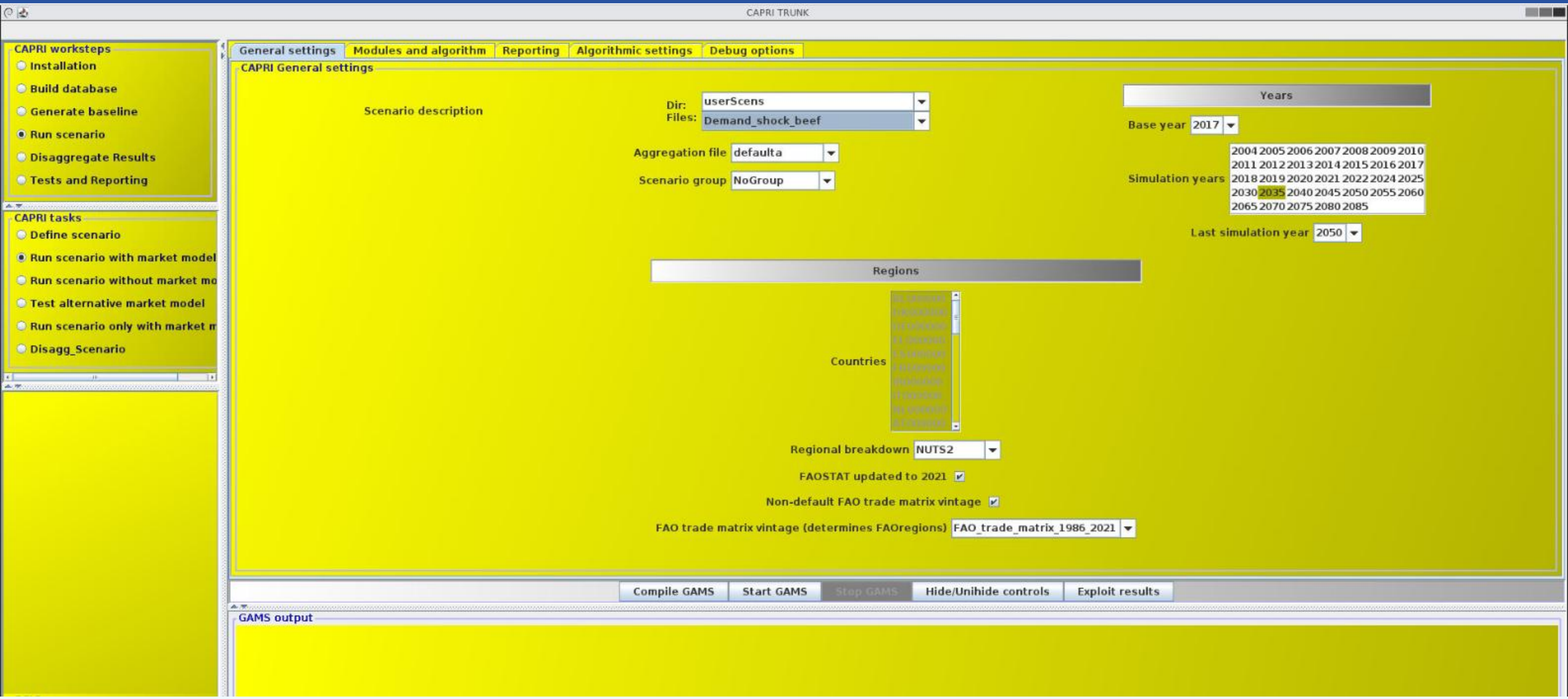
- **Substitution of beef calories with fruits, vegetables and legumes**

```
 p_dietChange(EU27_Brexit,"PercentageChange","%subst_veg%","%SIMY%") $ p_dietChange(EU27_Brexit,"calories_ref","%subst_veg%","%SIMY%")
*       ... increase in 50% of the absolute cut in meat calories
*     = 0.5*(p_dietChange(EU27_Brexit,"calories_ref","%cutmeat%","%SIMY%")-p_dietChange(EU27_Brexit,"calories_sim","%cutmeat%","%SIMY%"))
     = p_cutCons_v("%subst_veg%","%SIMY%")*(p_dietChange(EU27_Brexit,"calories_ref","%cutmeat%","%SIMY%")-p_dietChange(EU27_Brexit,"calories_sim","%cutmeat%","%SIMY%"))
*       ...relative to the reference run consumption of legumes and fruits&vegetables
     / p_dietChange(EU27_Brexit,"calories_ref","%subst_veg%","%SIMY%")*100;
 ;
```

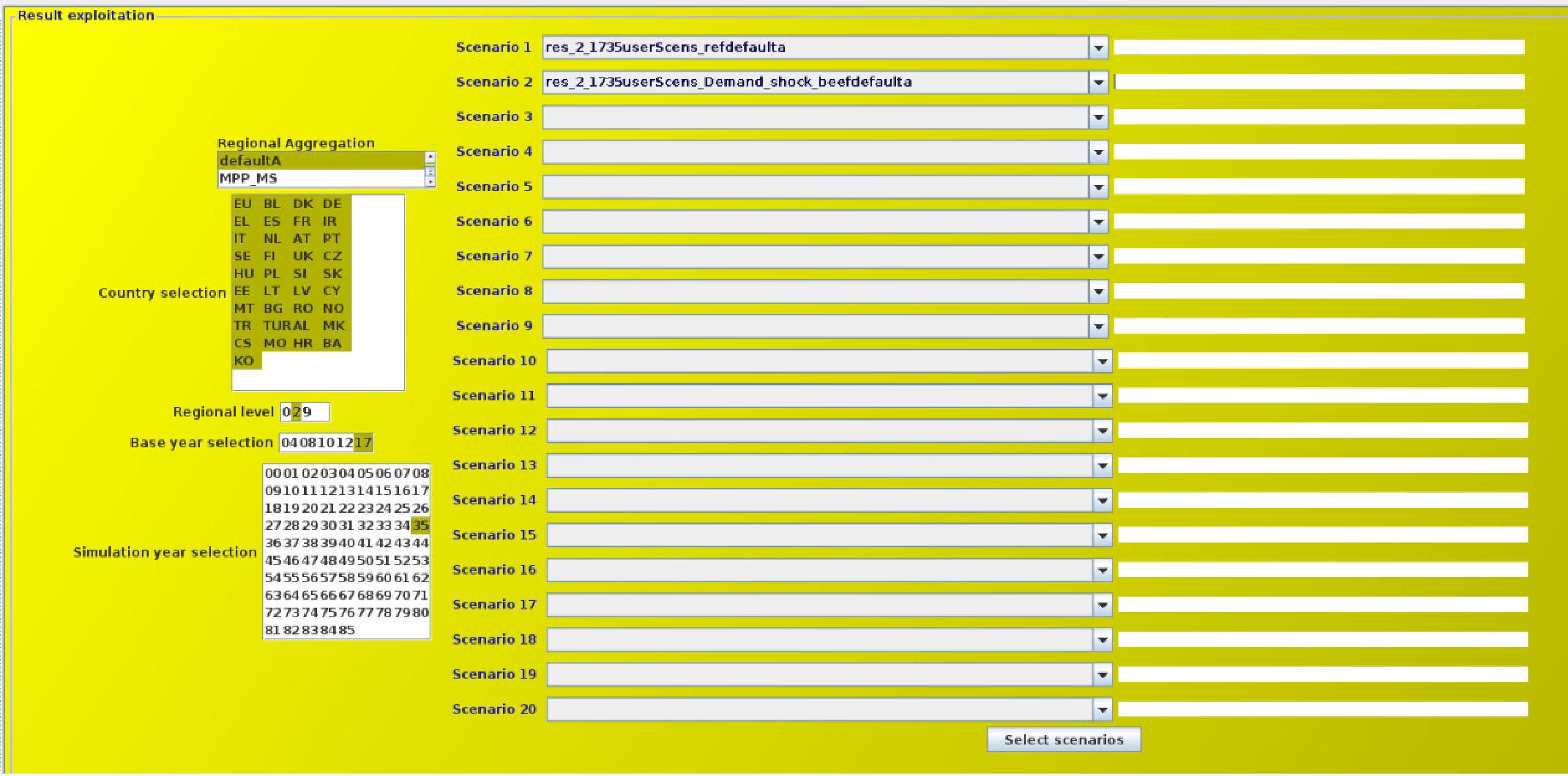
```
* --- define relative shift in legumes and fruits&vegetables consumption

 DATA(EU27_Brexit,"HCON",xleguveg,"PercentageChange") = p_dietChange(EU27_Brexit,"PercentageChange","%subst_veg%","%SIMY%");
```

CAPRI-Scenario „Demand_shock_beef.gms“



CAPRI-Scenario „Demand_shock_beef.gms“



Expectations for European agricultural sector

- Supply
- Prices
- Imports/Exports
- Nutrient balances (N-Surplus)
- Global warming potential

Exercise

1. The producer **price for beef** in the EU-27 changes by ________%
2. The country with the highest reduction in **beef meat activities** (number of animals), in **absolute terms**, is ________
3. The **beef supply** (1000t) in the EU-27 changes by ________%
4. The change in the **supply** of **fodder** (1000t) for the EU-27 is ________%
5. For the **EU beef exports without intra trade** change by ________% and **imports** by ________% *(Hint: "market balances without intra trade")*
6. For the **EU exports** of **vegetables and permanent crops without intra trade** change by________% and **imports** by ________%
7. Which are the **4 countries** in the **EU-27** with the **highest reduction in global warming potential from agriculture** in total terms

   1. ________ 2. ________ 3. ________ 4. ________

   (Hint: "Environment => Environmental indicators")
8. How high are the absolute changes in net emissions (1000t) (Total global warming potential) in the EU ________ Non-EU ________and World ________

   (Hint: "Emissions by commodity" => "Emissions for emission leakage")

Recent CAPRI studies

Rieger, J., Freund, F., Offermann, F., Geibel, I. & Gocht, A. (2023) From fork to farm: Impacts of more sustainable diets in the EU-27 on the agricultural sector. *Journal of Agricultural Economics*, 74, 764–784. https://doi.org/10.1111/1477-9552.12530

Himics, M., Giannakis, E., Kushta, J., Hristov, J., Sahoo, A. and Perez-Dominguez, I., 2022. Co-benefits of a flexitarian diet for air quality and human health in Europe. *Ecological Economics*, *191*, p.107232. https://doi.org/10.1016/j.ecolecon.2021.107232