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Modelling of Economic Equilibrium in the Agrarian Sector (The AGRO-2014 Model)

Abstract: *The article contains research results of the Institute of Agricultural Economics and Information (IAEI), Praha, for 2015, which focused on the development and use of the AGRO-2014 model. The model contains sections of agriculture, food processing, food retail (including catering without self-sufficiency), total food consumption (including catering and self-sufficiency) and food consumption per capita (in the detailed structure permitting nutritional evaluation). AGRO-2014 is a Leontieff's matrix-type model with a range of about 1,200 commodities. The model was used to calculate the total income and expenditure in the agrarian sector, to estimate the significance of imports and exports in this sector and to calculate an estimate of the trade margins on domestic and imported foods in the Czech Republic. Six variants of model simulations were calculated to calculate the coverage of the food consumption by the population in different sizes of the food exports and imports. Further on, the range of the trade margins on domestic and imported foods were analysed for 2007-2013. Model calculations did not confirm a hypothesis that market chains discriminate the Czech food against foreign competition.*

Keywords: *agrarian sector, mathematical modelling, AGRO-2014 model, economic equilibrium, Leontieff's matrix, agriculture, food production, retail, food consumption, trade margins*

Introduction

Agriculture is an important part of the national economy and food industry finalises and represents the agricultural production on the food market. For this reason, a macroeconomic model of production of agricultural products and their flows to food consumption by the population was created (AGRO-2014 model).

The AGRO-2014 model is a partial model of market equilibrium in the sector of food production and consumption, which consists of the following sections:
ZEM – section of agriculture;
POTR – section of food industry;
OBCH – section of retail;
SPOT – section of total food consumption, including self-sufficiency of the population;
SPOB – section of food consumption per capita (enables nutritional evaluation of population nutrition).

This model was used to calculate the equilibrium in the Czech agrarian sector, calculate financial sources which go through the agrarian sector, simulate dependency of the agrarian sector on exports and imports, and derive profit margins on domestic and foreign food products.

The AGRO-2014 model – structure of the model

ZEM section

Domestic production of the agricultural branch is in the AGRO-2014 model represented by commodities included in the Economic Accounts for Agriculture (EAA) of the Czech Republic.

The ZEM section contains dual model formulation for fruit and vegetables:
– aggregated form of "fruit total" and "vegetables total";
– disaggregated form for a detailed commodity structure of fruit (OVO section) and vegetables (ZEL section).

The second form is of particular importance in terms of food consumption and its nutritional evaluation.

POTR section

This section covers processing of domestic and foreign agricultural production in the Czech food industry which is based on data from the Czech Statistical Office (CZSO) "Production of selected food products" (CZ-NACE 10 and 11).

The choice of commodities was based on the following criteria:
Criterion 1: A limit was defined for a range of selected commodities >= 1000 tonnes.
Criterion 2: Every commodity must be traceable to the sale and consumption of food in the SPOB and OBCH sections.
Criterion 3: Selected commodities should cover that part of food production, which has originated in the ZEM section.

The choice of commodities according to criteria 1, 2 and 3 is contained in the model POTR10 (food production) and POTR11 (beverages) sections.

OBCH, SPOT and SPOB sections

Retail section (OBCH) and food consumption section (SPOT) represent the sale and consumption of food commodities by the population. These sections differ only by self-sufficiency.

The most important block of this section is food consumption per capita (SPOB1), which is published by the Czech Statistical Office.

Transformation of the SPOB1 block to the block of food sale in retail (OBCH1) is created by using indicators of the total population figures in the Czech Republic (excluding self-sufficiency). The SPOB1 block illustrates the overall quantity of food products provided by the retail network, catering (restaurants, schools, etc.) and self-sufficiency.

The next block is SPOB2 – food consumption per capita for nutritional evaluation, whose structure is different from the SPOB1 block, which follows the model calculation of the qualitative (nutritional) evaluation of nutrition. The SPOB2 block is connected with the OBCH2 block (just like the OBCH1).

Both SPOB1 and SPOB2 blocks have a common SPOB3 block of aggregate indicators of food consumption, which is connected in the model with the ZEM and POTR sections by the OBCH1 and OBCH2 blocks.

The AGRO-2014 model – mathematical description

Let $i = 1, 2, \ldots, n$ (n = 1200) be the commodity of the model, $A = A(i, j)$ a square matrix of $n*n$ type.

Element $A(i,j)$ represents the amount of a commodity i, which is consumed for the production of commodity j. Then the model can be described in the following equation system:

$$X(i) + IMP(i) + SELF(i) = sum\ (j = 1, \ldots, n, A(i,j) * X(j)) + EXP(i)$$

$$+ NEP(i)\ i = 1, \ldots, n,$$

where: IMP = import, SELF = self-sufficiency, EXP = export and NEP = non--food production (e.g. technical and other use of the commodity).

Solving the model system in EXCEL proceeds in the following iterative manner:
Let us denote:
X(i,0) – the initial state of solution X(i) as the input to the model, and
X(i,k) – the k-th approximation of the solution X(i) for k = 1, 2, etc.

Then the solution of the model is carried out according to the following algorithm (using symbols of the programming language ALGOL):

***Step 1**. Calls on the initial state solution X(i, 0) for i = 1 to n, other model parameters, i.e. the matrix A and vectors IMP, SELF, EXP and NEP are already entered.*

***Let** k := 0.*

***Step 2**. Take X(i, k) for i = 1 to n as a starting input in the step k (k = 0, 1, 2, etc.)*

***Step 3**. The equation system is solved by the assignment X(i, k) for i = 1 to n:*

*X(i, k+1) + IMP(i) + SELF(i) = sum (j, j = 1 to n, A (i, j) * X (j, k)) + EXP(i) + NEP(i) for i = 1 to n).*

***Step 4**. Solution X(i, k+1) is taken as a basis for the solution in the subsequent steps.*

***Step 5**. Criterion for the solution of the model:*

Let us calculate the difference between X(i, k) and X(i, k + 1)

*DIF(k) = **sum** (i, i = 1 to n, abs (X (i, k + 1) - X (i, k))).*

If** DIF(k) = 0, **then** X (i, k) is the solution of the model. **End

***If** DIF(k) > 0, **then** k : = k + 1; **go to Step 2**.*

Prices in the model

The ZEM section uses agricultural producer prices (CZV), the POTR section – food producer prices (CPV), and finally the OBCH and SPOT sections – consumer prices (SC). All prices are taken from monitoring of the CZSO.

CPV are officially monitored only for a small part of the food commodities. For this reason, they are included in the model prices derived from the monitoring of selected food products, which indicate for each commodity the physical

quantity and production values and sales. Then CPV are defined as share of the value and quantity.

For SC there is no reported assortment of food products that would exactly match the foods contained in the SPOB1 and SPOB2 sections. Consumer prices for all commodities were derived by analytical procedures and aggregations come from the official CZSO data.

The model is supplemented by import prices of agricultural and food commodities (DC) and export prices of agricultural and food commodities (VC), which are derived from the Czech custom statistics.

Margins in the model

An important part of the analysis and research of model prices are trade margins for food. Margins in foods can be defined by the following equations:

$SC(i) = CPV(j) + MAR(i)$ *for* $i \in SPOB2$, $i \in OBCH2$, $j(i) \in POTR$,

if the food product *i* from the monitoring of food consumption SPOB2 it is made in the food industry POTR, where it corresponds to the food product *j(i)* and it is delivered to OBCH2;

$SC(i) = CPV(j) + MAR(i)$ *for* $i \in SPOB2$, $i \in OBCH2$, $j(i) \in ZEM$,

if the food product *i* has its origin in the agriculture ZEM section and it is delivered directly to OBCH2;

$SC(i) = DC(j) + MAR(i)$ *for* $i \in SPOB2$, $i \in OBCH2$, $j(i) \in IMP$,

if the food product *i* is imported to the retail OBCH2.

Trade margins are not usually available (business secrets), and must be, therefore, estimated by various analytical and statistical methods.

Using of the AGRO-2014 model

The AGRO-2014 model enables to go from the standard statistical monitoring of food consumption or from the food consumption to the nutritional evaluation.

The AGRO-2014 model was calibrated in the course of 2015 on the real input data for 2013 (table 1).

Table 1. Food consumption (kg/capita/year) and its security in agricultural raw material; consumption of food and non-alcoholic beverages (annual per capita averages)

Food group	Consumption of food 2013	Agricultural raw materials	Reality 2013				Model calculations var. 0	
			heads / area	production	EXP	IMP	heads / area	production
	kg/capita		1000 hds / 1000 ha	1000 t	1000 t	1000 t	1000 hds / 1000 ha	1000 t
Beef in carcass weight	7.4	status of cows and cow suckler – slaughter production HM*)	564	164	93	42	508	196
Pork in carcass weight	40.4	total pigs – slaughter production VM*)	1,618	311	86	321	1,585	311
Poultry	24.2	poultry – slaughter production DM*)	21,464	235	90	152	25,478	277
Milk and dairy products in terms of milk	234.9	numbers of dairy cows – milk production	373	2,775	1,042	880	342	2,633
Eggs	13.5	hen – egg production	7,242	2,160	390	586	7,620	2,272
Vegetable edible fats and oils	16.8	total oilseeds – surface and production	460	1,504	603	158	472	1,528
Sugar	33.4	sugar beat – surface and production	62	3,308	475	376	47	2,354
Cereals total worth of free rice	106.8	total cereals – area and production	1,413	7,513	2,737	227	1,480	7,856
Potatoes	68.0	potatoes - area and production	23	536	130	413	32	721
Pulses	2.5	legumes total – area and production	18	38	0	0	18	38
Vegetables in terms of fresh	82.9	vegetables in total – area and production	13	177	95	581	9	168
Fruit in terms of fresh	76.8	fruit total - area and production	23	311	84	183	18	246
Total security		**main cash crops**	2,012				2,076	
		forage crops	451				464	
		permanent grassland, total	959				898	
		total agricultural land	3,548				3,449	

*** HM = beef, VM = pigmeat, DM = poultry meat**

Source: own calculations.

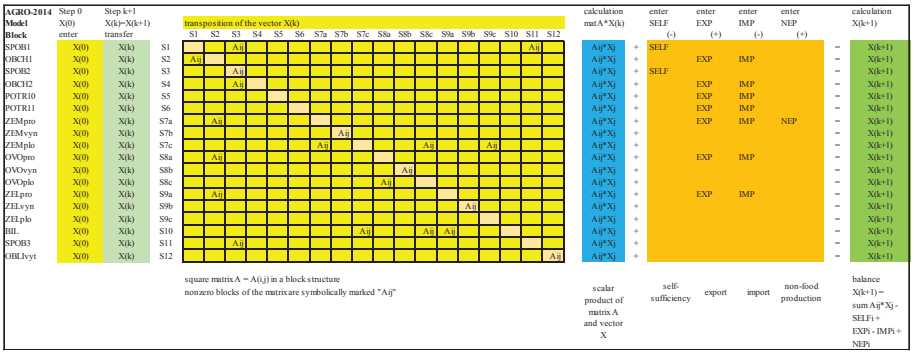

Figure 1. AGRO-2014 model – scheme of model links

The AGRO-2014 model was developed in block structure, which includes links between different sections and subsections of the agrarian sector, as illustrated in figure 1.

Estimate of total sales in the agrarian sector

With the help of the above-defined prices (CZV, CPV and SC) estimates of total sales in the agrarian sector and total expenditure of the Czech population for food products were calculated. These indicators can be described by the following equations (in ALGOL):

Revenues of agriculture (TRZzem), food industry (TRZpotr) and retail (TRZobch):

Let *TRZzem :=* ***sum*** *(i ∈ ZEM, CZV(i) * X(i)),*

Let *TRZpotr :=* ***sum*** *(i ∈ POTR10 + POTR11, CPV(i) * X(i)),*

Let *TRZobch :=* ***sum*** *(i ∈ OBCH2, SC(i) * X(i)),*

where X(i) is the solution of the AGRO-2014 model.

Revenues of the agrarian sector (TRZagro):

Let *TRZagro := TRZzem + TRZpotr + TRZobch,*

Let *VYDobyv :=* ***sum*** *(i ∈ SPOB2, SC(i) * X(i)),*

Let *VYDcel := VYDobyv * POCobyv,*

where VYDobyv is the average expenditure per capita for food products, POCobyv is the number of inhabitants.

In these equations the equality VYDcel = TRZobch holds true.

Results of the AGRO-2014 model calculations for 2013 have shown the following estimates:

TRZzem = CZK 122.7 billion (EAA of the CZSO show value 128.1),

TRZpotr = CZK 175.7 billion (in the official food industry monitoring is the value 282.9),

TRZobch = CZK 352.3 billion,

TRZagro = CZK 650.7 billion,

VYDobyv = CZK 33,521 per capita and year (official value is 27,367),

VYDcel = CZK 352.3 billion (official value is 287.7).

Estimate of the importance of exports and imports in the Czech agrarian sector

Exports (EXP) and imports (IMP) of commodities in the agrarian sector were implemented into the AGRO-2014 model in order to assess the relationship

between per capita consumption and a corresponding dimension of agriculture, depending on the extent of export and import.

Results of the model simulations (variants 0, 1, 2, …, 6) are based on the assumption that the standard food consumption per capita will be secured. Variant 0 (table 1) shows the real situation of 2013 (exports and imports on the level of 100%), other variants (tables 2 and 3) show impacts of percentage changes in volume of exports and imports on the size of the ZEM sector.

Table 2. Model calculations of security of food consumption of agricultural commodities

Agricultural raw materials	Reality 2013		Var. 1		Var. 2		Var. 3	
			EXP = 0	IMP = 100%	EXP = 0	IMP = 0	EXP = 100%	IMP = 0
	heads / area	production	heads / area	production	heads / area	production	heads / area	production
	1000 hds / 1000 ha	1000 t	1000 hds / 1000 ha	1000 t	1000 hds / 1000 ha	1000 t	1000 hds / 1000 ha	1000 t
Total numbers of cows – slaughter production HM*)	564	164	287	103	427	145	648	238
Total numbers of pigs – slaughter production VM*)	1,618	311	1,145	225	2,782	546	3,221	632
Poultry – slaughter production DM*)	21,464	235	17,205	187	31,201	339	39,474	429
Numbers of dairy cows – milk production	373	2,775	206	1,591	321	2,470	456	3,512
Hens – egg production	7,242	2,160	6,313	1,883	8,279	2,469	9,586	2,859
Total oilseeds – land and production	460	1,504	270	925	335	1,083	536	1,686
Sugar beat – land and production	62	3,308	40	1,879	46	2,255	53	2,730
Cereals total – land and production	1,413	7,513	821	4,231	1,307	6,890	1,966	10,515
Potatoes – land and production	23	536	26	592	44	1,004	50	1,134
Legumes total – land and production	18	38	18	38	18	38	18	38
Vegetables total – land and production	13	177	4	73	34	654	39	749
Fruit total – land and production	23	311	12	162	25	345	31	429
Total security								
main market crops	2,012		1,191		1,808		2,693	
forage crops	451		280		435		619	
permanent grassland, total	959		436		574		1,037	
total agricultural land	3,548		1,918		2,829		4,360	

*** HM = beef, VM = pigmeat, DM = poultry meat**

Source: own calculations.

Table 3. Model calculations of security of food consumption of agricultural commodities

Agricultural raw materials	Reality 2013		Var. 4		Var. 5		Var. 6	
			EXP = 0	IMP = 80%	EXP = 0	IMP = 60%	EXP = 100%	IMP = 40%
	heads / area	production	heads / area	production	heads / area	production	heads / area	production
	1000 hds / 1000 ha	1000 t	1000 hds / 1000 ha	1000 t	1000 hds / 1000 ha	1000 t	1000 hds / 1000 ha	1000 t
Total numbers of cows – slaughter production HM*)	564	164	315	111	343	120	371	128
Total numbers of pigs – slaughter production VM*)	1,618	311	1,473	289	1,800	353	2,127	417
Poultry – slaughter production DM*)	21,464	235	20,004	218	22,803	248	25,603	279
Numbers of dairy cows – milk production	373	2,775	229	1,767	252	1,943	275	2,119
Hens – egg production	7,242	2,160	6,706	2,000	7,100	2,117	7,493	2,234
Total oilseeds – land and production	460	1,504	283	956	296	988	309	1,020
Sugar beat – land and production	62	3,308	41	1,954	42	2,029	43	2,104
Cereals total – land and production	1,413	7,513	918	4,763	1,016	5,295	1,113	5,826
Potatoes – land and	23	536	29	674	33	757	37	839
Legumes total – land and production	18	38	18	38	18	38	18	38
Vegetables total – land and production	13	177	10	189	16	306	22	422
Fruit total – land and production	23	311	14	199	17	236	20	272
Total security								
main market crops	2,012		1,314		1,438		1,561	
forage crops	451	0	311	0	342	0	373	0
permanent grassland, total	959	0	463	0	491	0	519	0
total agricultural land	3,548	0	2,100	0	2,282	0	2,464	0

*** HM = beef, VM = pigmeat, DM = poultry meat**

Source: own calculations.

Variant 0 (EXP = 100% and IMP = 100%): The model results are very similar to reality in 2013. A certain difference is apparent in the head numbers of poultry, the total size of agricultural land, etc. These differences will be further considered as an approximation of the reality when analysing further variants.

Variant 1 (EXP = 0 and IMP = 100%): The results show that the Czech agrarian sector consumes almost 1.5 million ha for export production (about 43% of agricultural land). At the same time, it would be possible to reduce the size of animal production by about 150,000 dairy cows, 80,000 suckler cows, 4 million heads of pigs and 8 million heads of poultry.

Variant 2 (EXP = 0 and IMP = 0): This variant shows the high dependence of the Czech agrarian sector on imports. Very strong deficit shows the calculation of the requirements for the production of pork and poultry. On the other hand, beef consumption is fully covered by the domestic production. Total need of agricultural land is 2.8 million ha.

Variant 3 (EXP = 100% and IMP = 0): This variant shows a catastrophic and, therefore, unreal situation, if the Czech agrarian sector would maintain exports and all imports would be cancelled. In this case, all considered indicators would significantly exceed the reality. It is logical that these disproportionate demands on the ZEM sector would ultimately lead to the need for expansion of agricultural land by nearly 1 million ha, which is not available.

Variants 4-6 (EXP = 0 and IMP = 80%, 60% and 40%): These three variants simulate an effort to minimise the dependence of the Czech agrarian sector on imports. The critical factor is pork consumption, where it would be possible to consider a reduction to 70% import level (average of variants 4 and 5), while for the other indicators it could be considered 40% reduction of import level.

In strategic thinking about reduction of dependence of the Czech Republic on agricultural imports it would be alternatively possible to consider reduction in pork consumption from the actual level of about 40 kg per capita and year, eventually by substitution of pork meat by other types of meat, especially by poultry meat.

Estimation of margins for domestic and imported food products

Monitoring and calculations of margins methodically follow up research in 2014 (Foltýn et al., 2015). In 2015, the research was focused on model calculations (by the AGRO-2014 model) of margin development from 2007 (the average year), over 2009 (economy crisis period) to 2013 (the latest available year and beginning of economic growth).

Calculations were based on actual food consumption, which was considered as a "weight" for calculation of the average margins in the consumer basket.

Each food volume entering into the model was set to correspond to the actual total consumption in the monitored years. On this basis, the "real" consumption basket (in kg) and its total value (in CZK) were calculated according to the various types of prices in 2007, 2009 and 2013.

For SC model calculations VAT was deducted from the "consumer basket" value appropriate to the given year.

CPV are monitored only in a very narrow range of foods. Therefore, CPV from the AGRO-2014 model were used. For fruit, vegetables and potatoes producer prices from the ZEM sector were used, because these products are not processed in the food industry.

The source for DC data was the Czech foreign trade database (volume of imports and prices of imports).

All price types are not available for all monitored foods (CPV, SC and DC). Therefore, it was necessary to choose such food assortment for which it was possible to find CPV, SC and DC prices.

According to this rule, monitoring covered 3 variants, calculated and modelled, corresponding to different food product groups and individual products for which these prices were obtained and calculated. All variants were calculated for 2007, 2009 and 2013.

Table 4. Development of margins for domestic (CPV[1)]) and imported (DC[2)]) products for selected market basket of food (%) – variant 1

Food group	Margins 2007		Margins 2009		Margins 2013		CPV	DC
	CPV	DC	CPV	DC	CPV	DC	2013/07	2013/07
Beef	26.8	27.8	28.7	27.9	28.2	23.8	5.1	-14.2
Pigmeat	29.7	42.1	32.6	41.1	34.6	37.9	16.4	-10.1
Poultrymeat	25.8	17.9	14.7	33.3	21.6	27.4	-16.1	52.8
Meat products	37.0	27.0	37.1	30.8	39.7	26.8	7.1	-0.7
Fish	34.1	59.5	39.6	58.8	37.3	46.2	9.4	-22.3
Drinking milk	28.8	36.2	29.7	37.8	27.3	27.0	-5.2	-25.5
Processed cheeses	37.0	50.4	35.9	55.1	39.8	55.7	7.4	10.6
Other cheeses	24.4	41.1	33.8	42.0	37.9	37.8	55.4	-8.0
Milk powder	24.4	49.8	56.1	72.1	40.3	37.1	65.2	-25.5
Condensed milk	45.5	56.0	66.1	67.5	61.0	51.7	34.2	-7.6
Other dairy products	24.5	58.0	37.5	55.8	41.5	44.7	69.7	-22.9
Eggs	29.0	30.5	24.7	24.6	26.3	37.4	-9.3	22.7
Butter	23.9	33.3	16.8	17.8	22.7	19.8	-4.9	-40.5
Vegetable edible fats	28.0	23.6	33.8	42.2	26.3	32.0	-6.1	35.7
Sugar	21.3	14.7	22.4	22.4	30.9	19.3	45.3	30.9
Cocoa products	32.4	65.8	38.3	62.0	40.5	65.2	25.1	-0.9
Sugar confectionery	42.1	44.0	37.7	50.8	43.1	50.1	2.4	13.8
Wheat flour	23.1	20.6	34.4	34.9	30.6	22.3	32.4	8.2
Preserved bakery products	46.0	26.9	51.6	34.2	66.0	44.3	43.5	64.5
Pasta	47.6	26.3	47.0	19.8	40.7	24.4	-14.6	-7.1
Total	**30.8**	**38.9**	**34.0**	**41.6**	**37.1**	**38.5**	**20.4**	**-1.0**

1) Calculated according to the formula (SC-CPV)/SC.
2) Calculated according to the formula (SC-DC)/SC.
Source: own calculations of data from the Czech Statistical Office.

The first case (var. 1) includes food for which there exist all kinds of prices. For thus assembled "market basket" the total "fictitious" sum of expenditures was calculated in CPV, DC and SC for 2007, 2009 and 2013.

Based on the total value of the "consumer basket" margins were calculated according to the formula used by the CZSO (table 4). The results show what would be the total trade margin if the entire "market basket" would be filled with either only domestic products or only imported products.

Similar calculations were made in the fulfilment of the "consumer basket" by the food products of the Czech food producers only (var. 2) and by the imported products only (var. 3). These variants could use much broader "market basket" (more foods and food groups were comparable).

The model calculations imply that the trade margins for CPV and DC have been permanently closing. Margins calculated for the products of domestic origin increased (by 20.3%), while imported products stagnated (by minus 1%).

The difference between these two types of margins for the selected (relatively comparable) assortment represented in 2007, 2009 and 2013 the following values: 8.1, 7.6 and 1.4 percentage points, respectively.

It is clear that retailers have been trying to equate trade margins for the domestic (CPV) and imported (DC) food products so that the final consumer prices (SC) would be similar and appropriate to food demand.

Model calculations have further shown that the Czech producers are not discriminated against foreign competition.

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