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ECONOMIC-MATHEMATICAL BASES OF FORECAST MODELS OF AGRI-FOOD PRODUCTION AND CONSUMPTION IN ROMANIA

ABSTRACT

The time that has elapsed after 1989 until now represents a distinct period in the evolution of our country's economy, characterized by a clearly outlined evolution path. In statistical terms, this period provides data that makes it possible to approximate future trends in Romania's agri-food market size in the coming years. Specifically, the aim of this study is to establish a mathematical model describing the evolution of the twentieth century agriculture in France – a country that throughout the last century had a well-defined development tendency and has many similarities with our country in terms of agricultural potential. By transposing certain sequences of the mathematical model specific to the development trend in France, in the sense of completing the statistical data from 1990 onwards in Romania, we are going to anticipate our country's agri-food market possible evolution, at the 2035 time horizon.

Key words: mathematical modeling, forecasting, food production.

JEL Classification: C5.

1. INTRODUCTION

The mathematical modeling of certain evolution trends of the main indicators of Romania's agriculture at 2020–2035 horizon had its starting point in setting mathematical models for simulating forecast trends in Romania, whose basis lies in similar and/or identical phenomena having taken place in agriculture in other European countries with (relatively) similar ecological conditions. For this purpose, statistical data for agriculture in France in the period 1920–2010 have been processed, focusing on its evolution in the period 1960–2000, a segment that can represent a scenario worth reproducing (simulating) by Romania's agriculture.

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2. STATE OF KNOWLEDGE

At the beginning of the 18th century, the works by Jakob Bernoulli present a fundamental result in the theory of probabilities, known as the "law of large numbers". According to this, repeating a random experiment shall lead to a string of (empirical) results converging towards an expressed theoretical result, in the sense of the classical theory of probabilities. Thus, while studying a real random phenomenon, it is very important that initial data are found in a large enough volume, while ranging, at the same time, within the hypotheses of this result. More specifically, a larger number of observations minimizes the effects of randomness.

In our country, however, the many political changes in modern history tend to frustrate the possibility of ranging within the initial conditions of the theory set forth by Bernoulli; we refer here to major changes produced in the national economy, taking place at small timeframes, which hamper the activity of collecting a large number of statistical data for the purpose of estimating long-term evolution trends in the economy. However, the statistics of Eurostat (ec.europa.eu/eurostat), World Bank (http://data.worldbank.org/) or the National Institute of Statistics (www.insse.ro), on which the present study is based, indicates that the post-1989 period in Romania can be considered as quasi-stable and, although it does not represent a sufficiently long period of time, it begins to supply information which, related to an external model, allow us to outline certain evolution trends of the agri-food market size in Romania as well (Otiman et al., 2015).

3. THE MATHEMATICAL MODEL. STATISTICAL DATA

Table 1 presents the statistical information referring to the evolution of the average cereal yields in Romania and in France. We shall initially analyze the evolution of the average cereal yields in France in the period 1920–2010.

Table 1

Average cereal yields in Romania and in France 1920–2010 (kg/ha)

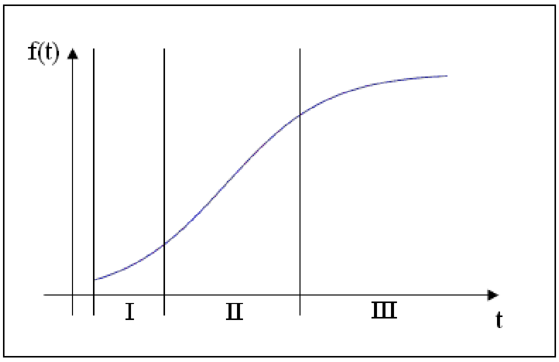
Year	Indicative	Statistical data: average yield in Romania	Statistical data: average yield in France
1920	1	1300	1100
1930	2	900	1200
1940	3	1000	1400
1950	4	800	1000
1960	5	1500	2800
1970	6	1900	4600
1980	7	3000	6400
1990	8	2800	7100
2000	9	2500	7300
2010	10	2800	7800

Source: Authors' processing of Eurostat, World Bank and INSSE data

We expected that the increasing evolution trajectory of average yields in cereals would already follow the already classical logistic model, visionary at that time, put forward by P.F. Verhuslt at the beginning of the 20th century. Even though initially the model was pointing towards the development of certain populations, under exponential dynamics, asymptotically limited at the maximum threshold, the model was borrowed and improved rapidly in the economic theories. As such, a form of this model is described within the equation:

$$f(t) = \frac{1}{\frac{1}{u} + b_0 \cdot b_1^t} \quad \text{(Figure 1),}$$

where t is the time variable, and u – superior development limit (upper bound).



Source: Graphic representation, Wolfram Alpha

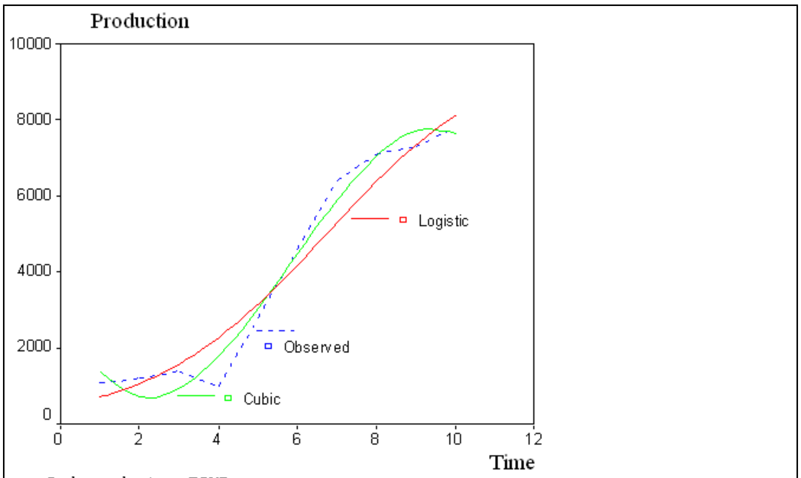
Figure 1. Logistic model.

The model successfully represents the statistical data from Table 1 (graphically represented under the shape of rectangles in Figure 2): initially, a first (I) development stage with a minor growth rate, corresponding to the years 1920–1950, followed by an accelerated period (II) for the years 1950–1990, then a capping tendency (III) specific to the present period, signalling out that it is fast getting closer to the biological maximum of cultivated species.

Following the information from Figure 3, we can notice that the statistical data are also well approximated by 3rd degree polynomials (cubic,

$$f(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3);$$

in both situations, the corresponding correlation coefficient (rsq, calculated using SPSS) is superior to the value of 0.9 at a high signification level, p (sigf.) < 0.0001. Thus, bearing in mind the much simplified expression of a polynomial model, and also the similarities with the logistic function chart (Figure 2 and Figure 1 *versus* Figure 3), we shall next prefer to use this model.

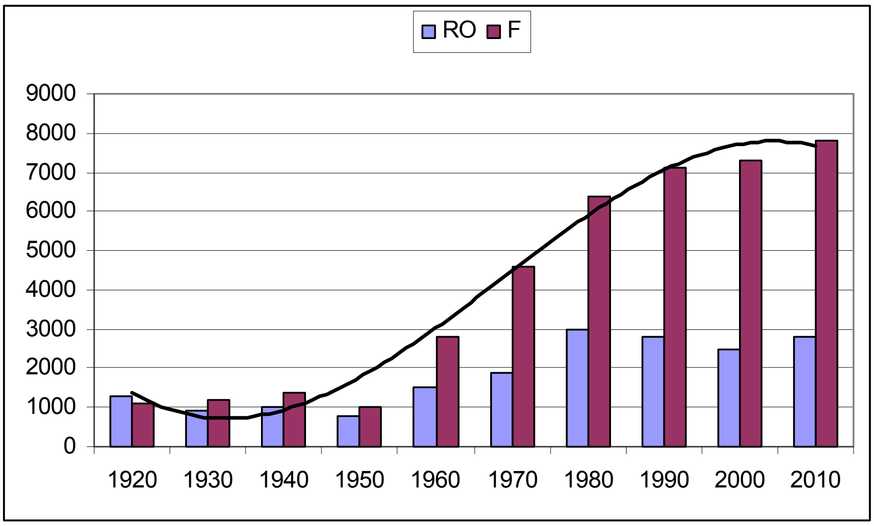


Independent: TIME

Dependent	Mth	Rsq	Sigf	Upper bound	b0	b1	b2	b3
PRODUCT	CUB	0,97	0,000		3136,67	-2360,4	655,245	-37,393
PRODUCT	LGS	0,91	0,000	10000	0,0020	0,6395		

Source: Processing Table 1 data using SPSS

Figure 2. Estimation of the mathematical evolution method for the average cereal yelds in France 1920–2010 (kg/ha).



Source: Graphic representation of Table 1 data

Figure 3. Average cereal yields obtained by Romania and France in one century (1911–2010) (kg/ha).

By direct comparison of data on average cereal yields in Romania and in France, we can notice a significant deviation from the tendency observed in France, with noticeable differences after 1950. Moreover, the capping tendency in Romania starts to develop at a value of around 3000 kg/ha, a non-compliant phenomenon when the issue is analyzed from an economic point of view.

4. RESULTS AND DISCUSSIONS

Let us now take a look at the national statistical data on own productions and agri-food consumption in the period 1990–2013 in Romania (Table 2).

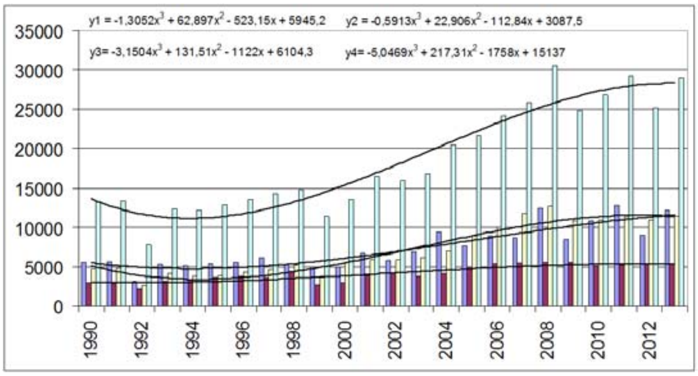
Table 2

Statistical data: agri-food productions, food consumption, Romania, 1990–2013 (mil. ECU/EURO)

Indicative/ year	Crop production y_1	Animal production y_2	Food production y_3	Total production y_4	Food purchasing expenditures	Food consumption expenditures from own-produced food	Food consumption from imports
1/1990	5518	3013	4720	13251			
2/1991	5634	2913	4819	13366			
3/1992	3048	2211	2546	7805			
4/1993	5242	3090	4084	12416			
5/1994	5130	3303	3701	12134			
6/1995	5342	3622	3854	12818	3710	5558	1088
7/1996	5530	3720	4273	13523	3860	5739	968
8/1997	6105	3598	4629	14332	3391	4511	711
9/1998	5317	4291	5161	14769	3902	4886	1021
10/1999	4991	2695	3769	11455	3143	4181	782
11/2000	4966	2988	5555	13509	3657	5253	932
12/2001	6717	3860	5892	16469	4452	4623	1245
13/2002	5786	4204	5885	15875	4320	4718	1081
14/2003	6902	3759	6149	16810	4417	4611	1313
15/2004	9399	4151	6994	20544	5435	5411	1557
16/2005	7716	5019	8895	21630	6538	5389	1836
17/2006	8888	5348	9935	24171	7273	5620	2196
18/2007	8607	5481	11840	25928	9087	7138	2976
19/2008	12421	5576	12635	30632	10224	7093	3770
20/2009	8434	5532	10843	24809	9556	6642	3366
21/2010	10791	5064	10949	26804	10042	7225	3297
22/2011	12785	5140	11325	29250	10005	8353	3744
23/2012	9015	5286	10898	25199	9468	7312	4105
24/2013	12184	5403	11395	28982	9960	7216	4310

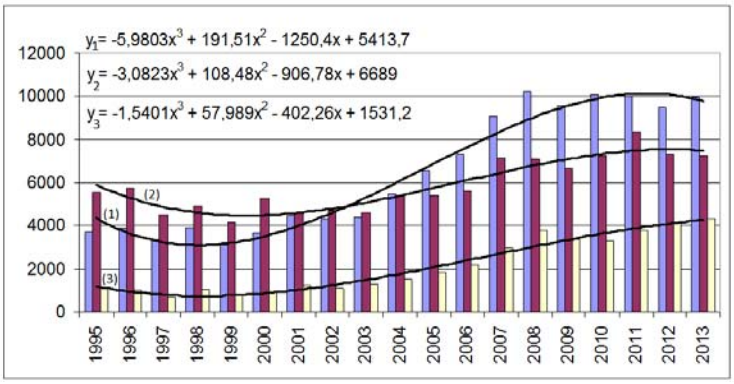
Source: Authors' processing of Eurostat, World Bank and INSSE data

We can find below the graphic representation of the statistical data above.



Source: Table 2 data graphic representation

Figure 4. Dynamics of agri-food production in Romania (1990–2013) (Crop production (1), Animal production (2), Food production (3), Total production (4)).



Source: Table 2 data graphic representation

Figure 5. Dynamics of agri-food consumption in Romania (1990–2013) (Food purchase expenditures (1), Food consumption expenses from own-produced food (2), Food consumption from imports (3)).

Following the national evolution trends of agri-food productions, we can obviously say that, compared to the logistic model, we find ourselves in stage II, the accelerated development period! All the four evaluated indicators, crop production, animal production, food production and total production show a double or even triple value multiplication compared to the 1990s. We are still far off stage III, the capping stage, determined by plant physiology, the livestock or food technological development frame. We can obviously say that, according to the statistical data, in the latest period of time (2004–2013), the value acceleration rate is growing.

Referring to the average cereal yields, we consider it opportune to compare the yield development rate in Romania in the current period with (approximately) that of the period 1950–1980 in France, a period of great technological changes in that country, quite similar to Romania's situation nowadays. From a mathematical point of view, if we were to impose the same angular coefficient

$$(\operatorname{tg}\alpha = \frac{y_2 - y_1}{t_2 - t_1})$$

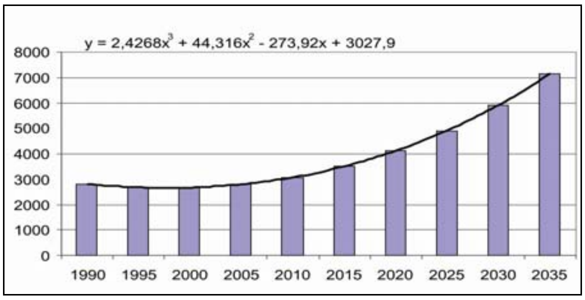
of the line describing the tendency of those years from the last century, in France, in order to estimate the national trends, for the 2005–2035 segment in Romania, we shall obtain the data below. The adjustment model used shall be a 3rd degree polynomial function.

Table 3
Estimation of average cereal yields in Romania, 1990–2035 (kg/ha)

Year	**Yield Estimated values (3rd degree)**
1990	2800.723
1995	2676.738
2000	2670.508
2005	2796.591
2010	3069.55
2015	3503.945
2020	4114.336
2025	4915.286
2030	5921.353
2035	7147.1

Source: Authors' processing of Eurostat, World Bank and INSSE data

The polynomial model (3rd degree) shown below describes/estimates the evolution trend for the average cereal yield in Romania for the entire period 1990–2035.



Source: Table 3 data graphic representation

Figure 6. Evolution / estimation trend of average cereal yields in Romania, 1990–2035.

Following the already outlined trend in Romania, we consider that the crop production estimates outlined below are achievable. Moreover, the trend of other indicators shall be estimated based on certain correlation relations, specific to homogenous economies, between crop production and agri-food production.

Table 4

Estimated crop production in Romania (mil. ECU/EURO)

Year	Indica-tive	Statistical data	Estimated values (3^{rd} dgr.)
1990	1	5500	5710.037
1995	2	5300	4643.296
2000	3	5000	5496.199
2005	4	7700	7820.768
2010	5	11000	11169.03
2015	***6***		***15092.99***
2020	***7***		***19144.69***
2025	***8***		***22876.14***
2030	***9***		***25839.37***
2035	***10***		***27586.4***

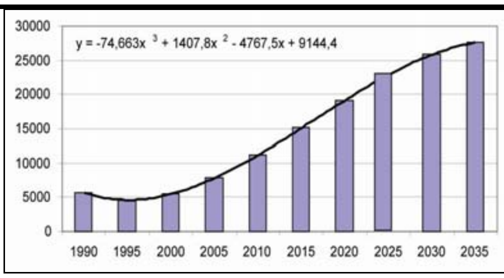


Figure 7. Crop production estimated in Romania (mil. ECU/EURO).

Source: Authors' processing of Eurostat, World Bank and INSSE data

Table 5

Estimated animal production in Romania (mil. ECU/EURO)

Year	Indica-tive	Statistical data	Estimated values (3^{rd} dgr.)
1990	1	3000	3293.926
1995	2	3600	3027.252
2000	3	3000	3269.23
2005	4	5000	4315.312
2010	5	5100	6460.95
2015	***6***		***10001.6***
2020	***7***		***15232.7***
2025	***8***		***22449.72***
2030	***9***		***31948.1***
2035	***10***		***44023.3***

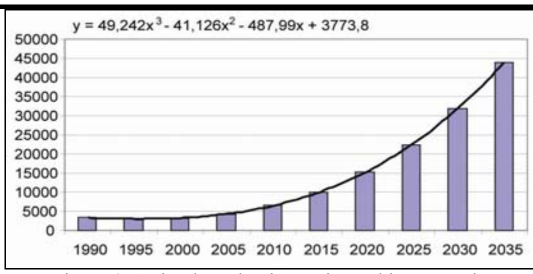


Figure 8. Animal production estimated in Romania (mil. ECU/EURO).

Source: Authors' processing of Eurostat, World Bank and INSSE data

Table 6

Estimated food production in Romania (mil. ECU/EURO)

Year	Indica-tive	Statistical data	Estimated values (3^{rd} dgr.)
1990	1	3000	3293.926
1995	2	3600	3027.252
2000	3	3000	3269.23
2005	4	5000	4315.312
2010	5	5100	6460.95
2015	***6***		***10001.6***
2020	***7***		***15232.7***
2025	***8***		***22449.72***
2030	***9***		***31948.1***
2035	***10***		***44023.3***

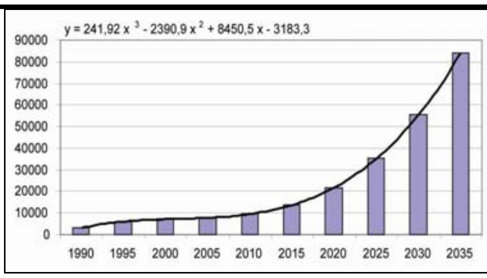


Figure 9. Food production estimated in Romania (mil. ECU/EURO).

Source: Authors' processing of Eurostat, World Bank and INSSE data

Table 7

Estimated total production in Romania (mil. ECU/EURO)

Year	Indica-tive	Statistical data	Estimated values (3^{rd} dgr.)
1990	1	11200	10322.25
1995	2	12500	13532.9
2000	3	13600	15814.75
2005	4	21600	19039.5
2010	5	27100	25078.85
2015	***6***		***35804.5***
2020	***7***		***53088.15***
2025	***8***		***78801.5***
2030	***9***		***114816.3***
2035	***10***		***163004.1***

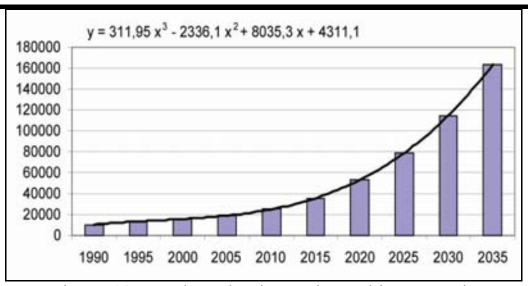


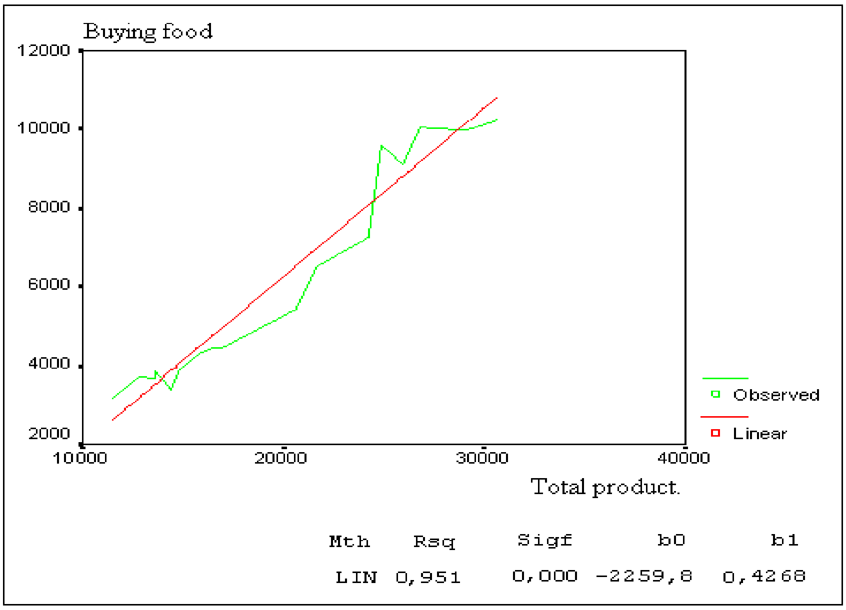
Figure 10. Total production estimated in Romania (mil. ECU/EURO).

Source: Authors' processing of Eurostat, World Bank and INSSE data

Total production, according to the statistical data for the period 1995–2013, correlates quite well, r>0.9 (calculation in SPSS), with the food purchase expenditures, the equation streaming from the relationship:

$$f(t) = -2259{,}8 + 0{,}4268t .$$

This relationship shall make it possible to estimate the value of food purchase expenditures (Table 8).



Source: Table 2 data processing by use of SPSS

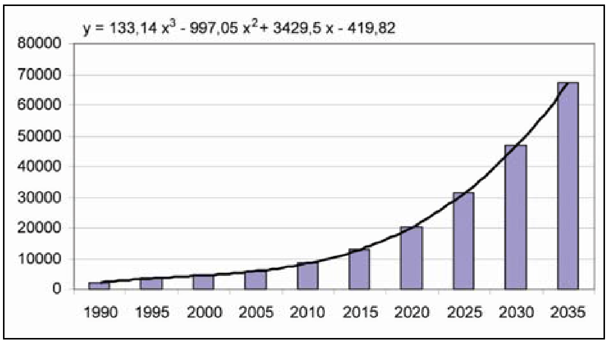
Figure 11. Setting a correlation relationship of total production with the food purchasing expenditures.

Table 8

Food purchase expenditures – estimated values

Year	Food purchase expenditures – estimated values
1990	2145.736
1995	3516.042
2000	4489.935
2005	5866.259
2010	8443.853
2015	***13021.56***
2020	***20398.22***
2025	***31372.68***
2030	***46743.8***
2035	***67310.35***

Source: Authors' processing of Eurostat, World Bank and INSSE data



Source: Table 8 data graphic representation

Figure 12. Estimated values for food purchase expenditures (mil. ECU/EURO).

5. CONCLUSIONS

The study started from the statistical data on average cereal yields in Romania in the period 1920–2010, and the forecast method was based on an adjustment that relies on the hypothesis of Romania's following a development trend similar to that in the period 1950–1980 from France. The other data are based on correlations between cereal production and other indicators of the evolution stage at agri-food level. Bearing in mind the random features and, subsequently, the subjectivity that has permanently accompanied an economic forecast study, we may not offer values clearly expressed by statistical indicators to describe the reliability level in relation to the obtained results.

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