Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 2, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

MATHEMATICAL MODELS DESCRIBING THE DYNAMICS IN AVERAGE PRICES AND PURCHASED QUANTITIES OF FRESH FRUITS

Delyana DIMOVA

Agricultural University - Plovdiv, 12 Mendeleev Blvd, Plovdiv 4000, Bulgaria; E-mail: delyanadimova@abv.bg

Corresponding author: delyanadimova@abv.bg

Abstract

Data on product categories and hierarchical relationships among them are presented in a built relational database. Fresh fruits category, including 14 product types (cherries and morellos, apples, peaches and apricots, grapes, etc.) is the subject of consideration in this work. The article presents mathematical models describing the dynamics in average prices and purchased quantities of fresh fruits, average per household in Bulgaria. The examined period covers generally 17 years from 2001 to 2017. Linear and quadratic equations have been constructed and analyzed. The results show a growth in purchased quantities, average per household for almost all studied fresh fruits. A similar situation occurs with the other examined indicator. An increase in the average prices of the 14 fruit types has also been observed for the surveyed period, while for some of them (grapes, plums, pears, cherries and morellos, strawberries and raspberries), compared with the rest, this process has been more intensive.

Key words: *average prices, fresh fruits, linear and quadratic models, purchased quantities*

INTRODUCTION

Relational database management systems have become ubiquitous components of modern application software [10]. Each relational database management system uses two languages: data definition language for defining a relational database schema and data manipulation language for storing and retrieving data [14]. A relational schema specifies various properties of tables and columns within tables, the most important of which is the type of data contained in each column [15]. The relational database strongly supports security, consistency and avoids the redundancy of records [12].
Mathematical models are a useful tool in describing the dynamics of agricultural production regarding various products from the vegetal or animal sector and their prices at delivery, and also for studying the purchasing power of the households for various food products [2, 3].
Information concerning food and non-food products has been extracted from the web site of Bulgarian National Statistical Institute [11]. The indicated product categories and hierarchical relationships among them have been presented in a created relational database [1].

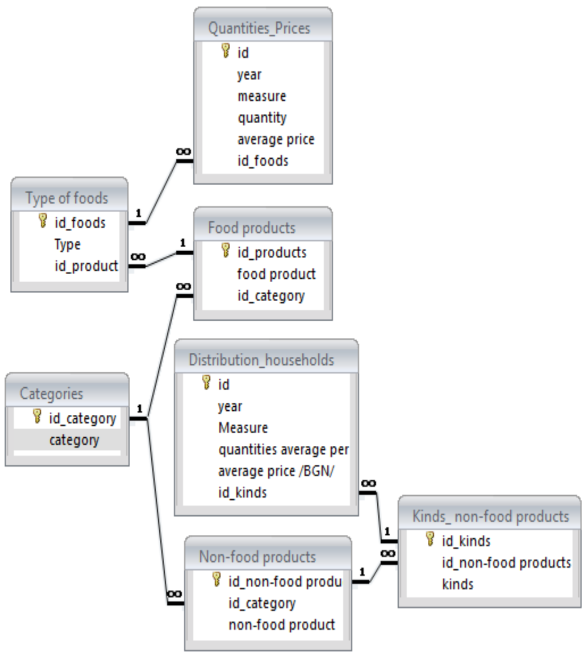

Fig. 1. Scheme of the database
Source: Own conception.

In this respect, Figure 1 presents the schema of seven tables which describe the relations between various product categories and

average quantities, average prices and also average quantities per 100 households.
The tables shown in Figure 1 are:
- Categories (id_category, category);
- Food products (id_product, food product, id_category);
- Non-food products (id_non-food products, id_category, non-food product);
- Type of foods (id_foods, id_product, type);
- Quantities_Prices (id, year, average price, measure, quantity, id_foods);
- Kinds_non-food products (id_non-food products, id_kinds, kinds);
- Distribution_households (id, year, measure, average price, quantities average per 100 households, id_ kinds).

Different datasets obtained from the listed database tables can be processed. For this purpose, certain mathematical-statistical methods for analysis [13], [6] and assessment can be applied. Some of them are regression and correlation analysis. Regression analysis forms the core for a family of techniques including path analysis, structural equation modelling, hierarchical linear modelling, and others [7]. While correlation analysis helps in identifying associations or relationships between two variables, the regression technique or regression analysis is used to "model" this relationship so as to be able to predict what will happen in a real-world setting [5]. This work considers part of the exposited issues about data concerning certain food products.

The aim of the article is to present mathematical models describing the dynamics in average prices and purchased quantities of fresh fruits for the period from 2001 to 2017 in Bulgaria.

MATERIALS AND METHODS

The created database stores information about the two main product categories for 17 years time interval. They include 20 food and 11 non-food products, respectively. The number of food product types is 79 and the number of non-food product types is 31.

The fresh fruits category has been studied in this work. It contains the following 14 product types:
- Cherries and morellos;
- Apples;
- Peaches and apricots;
- Pears;
- Plums;
- Strawberries and raspberries;
- Grapes;
- Olives;
- Watermelons and melons;
- Pumpkins.

The main surveyed economic indicators for the listed products include:
- Average prices;
- Purchased quantities, average per household;
- Period (examined years).

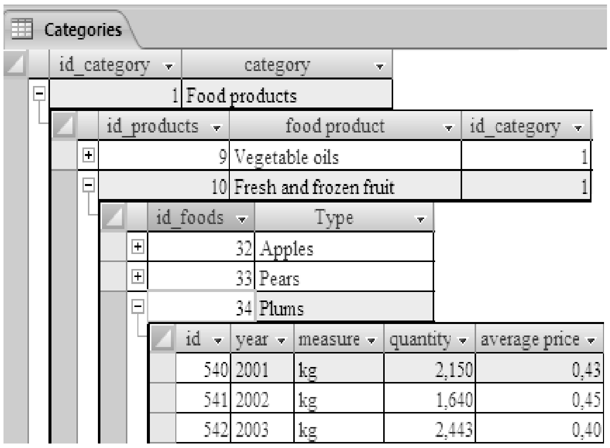

Fig. 2. Visualization of the information from the database tables
Source: Data from the National Statistical Institute, Bulgaria [11].

Information related to fresh fruits category has been presented in four database tables - Categories, Food products, Type of foods, Quantities_Prices (Fig. 2). The use of certain parameters (criteria) makes it possible to find the respective records from the tables. Subsequently, these data have been stored and processed. In this connection, it is necessary to calculate:
- The differences - $P_{i+1\,j}$ and $Q_{i+1\,j}$

$$P_{i+1\,j} = p_{i+1\,j} - p_{i\,j} \quad (1)$$

$$Q_{i+1\,j} = q_{i+1\,j} - q_{i\,j} \quad (2)$$

where: $p_{i+1\,j}$ and $p_{i\,j}$ - average prices of j^{-th} product for current and preceding year, $1 <= i <= 16$, $1 <= j <= 10$;

$q_{i+1\,j}$ and $q_{i\,j}$ - purchased quantities of j^{-th} product, average per household for given and preceding year.

If any of the examined differences ($P_{i+1\,j}$ or $Q_{i+1\,j}$) is greater than zero, then the relevant indicator (average price or purchased quantity) grows in the given year. Otherwise, that is, if $P_{i+1\,j} < 0$ or $Q_{i+1\,j} < 0$, then the value of the indicator decreases;

- The percentage change of the referred variables (purchased quantities, average per household and average prices) for each year compared with the preceding one:

$$g_{i+1\,j}\% = \frac{q_{i+1\,j}.100}{q_{i\,j}} - 100 \qquad (3)$$

$$v_{i+1\,j}\% = \frac{p_{i+1\,j}.100}{p_{i\,j}} - 100 \qquad (4)$$

The considered indicators have been studied in the years between 2001 and 2017. Linear and quadratic models have been constructed and analyzed. Software packages such as MS Excel [8] and R Commander [4], [9] have been used for the data processing.

RESULTS AND DISCUSSIONS

Information about each of these 14 fruits types has been searched from the database tables. For this purpose the parameter queries have been created and used. The necessary information has been extracted depending on the entered parameters (certain indicator, types of fruit, time period). As a result, the obtained information from the database about these objects has been stored in an xlsx file and has been analyzed.

The calculated values of the variable Q_{i+1j} are negative for 4 consecutive years about two of the examined products (grapes and pumpkins) as follows: for the first of them from 2002 until 2005, and for the second one in the period 2004-2007. Therefore, the purchased quantities of the referred products, average per household in the indicated time intervals continuously reduced. As can be expected, the lowest indicator values for the considered two fruit types were registered in 2005 and 2007 respectively. One interesting fact should be noted. The surveyed difference Q_{i+1j} is positive in the years between 2006-2009 for the grapes, whereas for the other product - pumpkins this period includes 2011-2014. A similar situation was observed for the purchased quantities, average per household about the following fruits: watermelons and melons, apples and plums. In this case, the number of the consecutive years is three. The indicator grew for the first two products in 2006-2008, while for the other two products in 2005-2007, 2012-2014 and 2007-2009, 2011-2013, respectively.

The reverse process, i.e a reduction of the purchased quantities of watermelons and melons was observed during 2003-2004. The case is similar for this examined indicator about the apples in 2015-2017, as well as about the plums in 2004-2006. The calculated values of the variable Q_{i+1j} ($4<=i<=9$, $j=5$) for olives are greater than 0, therefore a continuous growth of the purchased quantities of the indicated fruit was established over the interval 2004-2009. Periods are alternated during the other years in which this indicator for each of the listed products reduce and then increase or vice versa.

The values of the variable g_{i+1j} (percentage change of purchased quantities) are significantly higher for apples in the 2^{nd}, for pears in the 5^{th}, for cherries and morellos in the 13^{th} and for plums in the 16^{th} year from the studied interval (Fig. 3). While the lowest values for the same indicator were observed for peaches and apricots in the 2^{nd}, for pears in the 6^{th} and for strawberries and raspberries in the 7^{th} year from the considered period. As a whole, the limits within which the variable g_{i+1j} varies are the smallest for the olives in comparison with those for the other investigated fruits.

The dynamics of change in purchased quantities of the examined 14 fruit types has been tracked and analyzed in the interval 2001-2017. Linear and quadratic models have been used for this purpose. The construction of the referred models requires finding the parameters of the listed regression equations.

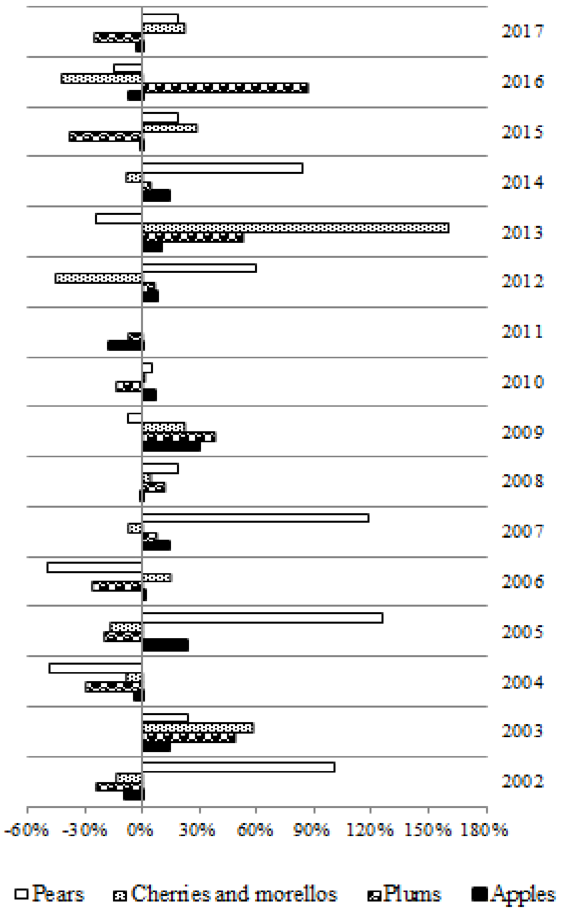

Fig. 3. Percentage change of the purchased quantities, average per household
Source: Own calculations on the basis of data from National Statistical Institute [11].

They are presented in Table 1, as well as the calculated determination coefficients (R^2). It should be noted that the linear and quadratic equations concerning surveyed data on watermelons and melons are not adequate. The results of the analysis showed that the variations in the data about the other fruit types are best described by second-degree polynomials. The presented models are adequate at 5% level of significance. In addition, the obtained linear equations for purchased quantities of plums, strawberries and raspberries for the examined interval are also not adequate.

A decreasing tendency in the purchased quantities of grapes, cherries and morellos, average per household was established at the beginning of the period. A gradual increase of the variable was observed for 2007-2019, with the exception of some individual years in which a certain decline was registered.

A llittle different was the situation with the examined indicator for apples. The increase in the purchased quantities of this fruit, average per household is significantly higher in comparison with the other fresh fruits, although a slight decline is observed for the last 3 years of the time interval.

Table 1. Results of the analysis

Fresh fruits	**Linear equations**	**R²**	**Quadratic equations**	**R²**
Watermelons and melons	y = 0.351x+22.85	0.140	$y = 0.002x^2+0.310x+22.98$	0.140
Apples	y = 0.930x+10.76	0.861	$y = -0.033x^2+1.534x+8.848$	0.884
Grapes	y = 0.269x+5.016	0.549	$y = -0.005x^2+0.364x+4.716$	0.553
Peaches and apricots	y = 0.302x+4.254	0.738	$y = -0.001x^2+0.331x+4.160$	0.738
Olives	y = 0.156x+3.078	0.882	$y = -0.005x^2+0.248x+2.787$	0.900
Plums	y = 0.027x+1.517	0.073	$y = 0.014x^2–0.227x+2.323$	0.443
Cherries and morellos	y = 0.074x+1.081	0.452	$y = 0.002x^2+0.029x+1.223$	0.461
Strawberries and raspberries	y = 0.018x+1.145	0.068	$y = 0.009x^2–0.143x+1.659$	0.375
Pumpkins	y = 0.080x+1.001	0.582	$y = 0.008x^2–0.074x+1.493$	0.708
Pears	y = 0.068x–0.020	0.822	$y = 0.004x^2–0.016x+0.248$	0.896

Source: Own calculations on the basis of data from National Statistical Institute [11].

The values of the indicator for peaches and apricots, olives, pumpkins and pears increased steadily over most of the period. Only the purchased quantities of strawberries and raspberries, average per household remained unchanged during 2009-2012, but in 2016-2017 this variable decreased slightly.

The obtained determination coefficient (R^2) for the surveyed data about olives is higher in comparison with the others. Its value is 0.90. This means that the time explains 90% of the variations in the purchased quantities of this fruit, average per household. The lowest value of this examined variable was calculated for strawberries and raspberries. In the case, it is 0.375 (Table 1). Therefore, the time explains 37.5% of the variations in the purchased quantities of the indicated fruits.

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 2, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

Data for the second studied indicator have been also analyzed. Generally, an increase in the average prices of the 14 fruit types has been observed for the 17 years period, while for some of them (grapes, plums, pears, cherries and morellos, strawberries and raspberries), compared with the rest, this process has been more intensive.

The values of the differences P_{i+1j} are negative for certain years, but the decline of the investigated indicator is small. The increase of the average prices of watermelons and melons, plums, pumpkins, cherries and morellos is over 2.5 times, while for the other fruit types in the range between 1.54 and 2.48 times. It should be noted that the growth of the average prices of apples is the least.

The calculated values of variable v_{i+1j} (over 50%) are much higher respectively for peaches in the 2^{nd}, for pumpkins, strawberries and raspberries in the 7^{th} year from the considered time period. High values of this variable (over 35%) were also observed for watermelons and melons in 2003, for grapes in 2005 and for cherries and morellos in 2016 (Fig. 4).

The dynamic changes in the average prices of the studied fruit types for the 17 years interval are presented analytically with the equations shown on Table 2. The described models (linear and polynomials of the second degree) are adequate at 5% significance level. The obtained values of the determination coefficients about the surveyed data for each fruit were compared. The results showed that the variations in average prices of fresh fruits are best described with the second degree polynomials.

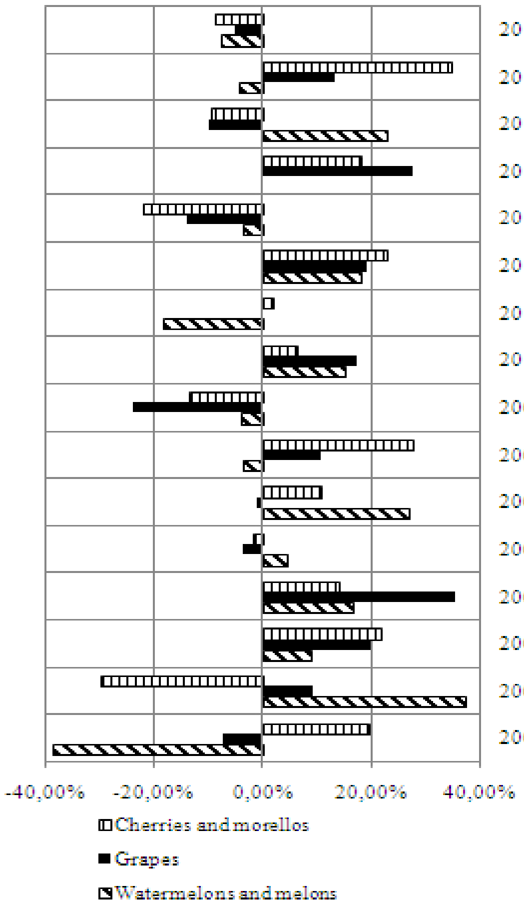

Fig. 4. Percentage change of the average prices of some studied products
Source: Own calculations on the basis of data from National Statistical Institute [11].

Table 2. Visualization of the constructed regression models

Fruit types	Linear equations	R^2	Quadratic equations	R^2
Watermelons and melons	y=0.021x+0.309	0.779	$y = -0.001x^2+0.038x + 0.256$	0.807
Apples	y=0.018x+1.101	0.433	$y = -0.002x^2+0.057x + 0.977$	0.548
Grapes	y = 0.043x+0.689	0.766	$y = -0.001x^2+0.069x + 0.609$	0.781
Peaches and apricots	y = 0.033x+1.025	0.600	$y = -0.001x^2+0.057x + 0.949$	0.618
Olives	y = 0.170x+3.361	0.938	$y = -0.004x^2+0.258x + 3.083$	0.952
Plums	y = 0.033x+0.450	0.592	$y = -0.004x^2+0.108x + 0.211$	0.770
Cherries and morellos	y = 0.097x+1.308	0.802	$y = 0.001x^2+0.083x + 1.354$	0.803
Strawberries and raspberries	y = 0.158x+1.25	0.882	$y = -0.002x^2+0.205x + 1.099$	0.887
Pumpkins	y = 0.019x+0.373	0.516	$y = -0.001x^2+0.054x + 0.264$	0.608
Pears	y = 0.074x+1.170	0.829	$y = -0.001x^2+0.105x + 1.073$	0.838

Source: Own calculations on the basis of data from National Statistical Institute [11].

The calculated determination coefficient has the highest value for olives. It is 0.952. This means that the time explains 95.20% of the variations in the average price of this fruit. The lowest value of the surveyed variable (R^2) is obtained for apples. In this case, the coefficient of determination is 0.548. Therefore, the time explains 54.80% of the variations in the average price of the apples.

CONCLUSIONS

The information concerning various food and non-food products has been organised and stored in a built relational database. Fresh fruits category containing 14 product types has been studied in the current article. Applying a certain set of criteria, the searched information about the referred objects has been extracted from the database. The obtained data have been saved in a separate xlsx file and have been processed. Linear and quadratic models are used to describe the dynamics in average prices and purchased quantities of fresh fruits, average per household. The considered period includes the years from 2001 to 2017.

The obtained results from this study show that the linear equations concerning the data on purchased quantities of watermelons and melons, plums, strawberries and raspberries, average per household are not adequate. Similar is the situation with the quadratic equation for the data about watermelons and melons. The other described models (linear and polynomials of the second degree) are adequate at 5% significance level.

The values of the purchased quantities of watermelons and melons, average per household in some of the considered years changed significantly. A growth of this studied indicator for the other fresh fruits was established for the indicated period.

The increase in average prices of seven fresh fruits types (grapes, plums, pears, cherries and morellos, strawberries and raspberries) was more intensive in comparison with the rest ones.

REFERENCES

[1]Dimova, D., 2018, An Approach for Managing and Comparing Data concerning Some Main Food Products, 18th International Multidisciplinary Scientific GeoConference SGEM 2018, Bulgaria, Vol. 18, Issue: 2.1: 55-62.

[2]Dimova, D., 2021, Comparative analysis of the rabbit meat production in Balkan countries, members of the European Union, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(1):227-232.

[3]Dimova, D., 2021, Survey of the purchasing power of households concerning certain milk products, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol.21(1):233-236.

[4]Fox J., 2005, The R Commander: A Basic-Statistics Graphical User Interface to R, Journal of Statistical Software, Austria, Vol. 14(9): 1-42

[5]Gogtay, N.J., Deshpande, S.P., Thatte, U.M., 2017, Principles of Regression Analysis, Journal of the Association of Physicians of India, India, Vol. 65, 48-52.

[6]Keranova, N., 2017, Mathematical Approaches for Study and Analysis of the Land Market in Bulgaria, Scientific journal «Economics and Finance», Perspectives of research and development, SAUL Publishing Ltd, Dublin, Ireland, 95-99.

[7]Klees, S. J., 2016, Inferences from Regression Analysis: are they valid?, Real-world economics review, Issue 74, 85-97, http://www.paecon.net/PAEReview/issue74/Klees74.pdf, Accessed on Nov. 6th, 2020.

[8]Levine, D. M., Stephan, D. F., Szabat, K. A., 2016, Statistics for Managers using Microsoft Excel, 8th edition, Pearson, USA.

[9]Logan, M., 2008, R with Rcmdr: Basic Instructions. 1-29. Monash University, http://users.monash.edu.au/~murray/stats/BIO3011/Rmanual_paper.pdf, Accessed on Nov. 6th, 2020.

[10]Malecha, G., Morrisett, G., Shinnar, A., Wisnesky, R., 2010, Toward a Verified Relational Database Management System, POPL '10: Proceedings of the 37th Annual ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages, Spain, 237-248.

[11]National Statistical Institute, Bulgaria, http://www.nsi.bg, Accessed on Nov. 7th, 2020.

[12]Rai, P. K., Singh, P., 2015, Studies and Analysis of Popular Database Models. International Journal of Computer Science and Mobile Computing, India, Vol. 4(5): 834-838.

[13]Paidi, A. N., 2012, Data Mining: Future Trends and Applications, International Journal of Modern Engineering Research, India, Vol. 2(6): 4657-4663.

[14]Wojnicki, I., Janikow, C.Z., 2003, Extending Data Processing Capabilities of Relational Database Management Systems, International Conference on Artificial Intelligence, Las Vegas, Nevada, USA, Vol. 1, 388-393.

[15]Zhang, M., Hadjieleftheriou, M., Ooi, B. C., Procopiuc, C. M., Srivastava, D., 2011, Automatic Discovery of Attributes in Relational Databases, Proceedings of the 2011 ACM SIGMOD International Conference on Management of data, Greece, 109-120.