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# THE USE OF REGRESSION MODELLING TO DESCRIBE CHANGES TAKING PLACE ON THE AGRICULTURAL MARKET IN POLAND®

## Wykorzystanie modelowania regresji do opisu zmian zachodzących na rynku rolnym w Polsce®

**Key words**: agricultural market, non-linear regression analysis, modelling, milk production, wholesale supplier.

*The article presents a way of the application of regression analysis model to describe the phenomenon of the changing number of wholesale milk deliveries with respect to the number of wholesale suppliers on the agricultural market. In the process of mathematical regression, non-linear functions were used, where the independent variable was time. The data collected from the institution governing the milk production quota mechanism clearly shows that, during its operation, the national milk quota increased while the number of both wholesale and direct suppliers decreased. This situation resulted in an increased average individual quota per supplier. These results reflect the decreasing number of Polish farms maintaining dairy cattle in the country as a result of the shift from milk production in small farms to commercial production in farms developing in this sector. It should also be noted that the changes in the concentration of production are also linked to an increase in the quality of the raw material and final product. This tendency supports the fact that the dairy industry is becoming an increasingly specialized and forward-looking industry, as can already be seen from the consumer's perspective on the food products market today.*

*Although many authors have addressed the economic implications of the existing dairy price support scheme, few have explicitly considered the relationship between risk aversion, capital investment, milk production and price support policy in this process.*

**Słowa kluczowe:** rynek rolny, analiza regresji nieliniowej, modelowanie, produkcja mleka, dostawca hurtowy.

*W artykule przedstawiono sposób zastosowania modelu analizy regresji do opisu zjawiska zmiany liczby dostaw mleka w hurcie w stosunku do liczby dostawców hurtowych na rynku rolnym. W procesie regresji matematycznej wykorzystano funkcje nieliniowe, gdzie zmienną niezależną był czas. Z danych zebranych od instytucji rządzącej mechanizmem kwotowania produkcji mleka jasno wynika, że w trakcie jego funkcjonowania wzrosła krajowa kwota mleczna, a zmniejszyła się liczba zarówno hurtowych, jak i bezpośrednich dostawców. Sytuacja ta spowodowała wzrost średniej kwoty indywidualnej na dostawcę. Wyniki te odzwierciedlają zmniejszającą się liczbę polskich gospodarstw utrzymujących bydło mleczne w kraju w wyniku przejścia od produkcji mleka w gospodarstwach małych, do produkcji towarowej w gospodarstwach rozwijających się w tym sektorze. Należy również zauważyć, że zmiany w koncentracji produkcji są również związane ze wzrostem jakości surowca i produktu końcowego. Tendencja ta potwierdza fakt, że branża mleczarska staje się coraz bardziej wyspecjalizowaną i przyszłościową branżą, co widać już z perspektywy konsumenta na dzisiejszym rynku produktów spożywczych. Chociaż wielu autorów odniosło się do ekonomicznych implikacji istniejącego programu wsparcia cen mleka, niewielu wyraźnie rozważyło związek między awersją do ryzyka, inwestycjami kapitałowymi, produkcją mleka i polityką wspierania cen w tym procesie.*

## INTRODUCTION

The role of the European Union's common economic policy, based on the implementation of its respective policies, is to enhance its competitiveness in the global economy. It is therefore the aim and interest of the EU as a global player in the economy to increase the competitiveness of EU members in, among other things, agricultural production in relation to the marketing of these goods. Competitiveness is essential to maintain productivity growth and raise living standards, especially in small open economies that rely on international trade and are highly dependent on foreign direct investment [1, 11, 12].

Forecasting the production of agricultural products is an important theoretical and practical element. In 2008

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a sudden increase in product prices was observed. These prices fell in following years. However, since around year 2000, an increasing trend in agricultural product prices could be observed. This can be clearly seen when analyzing the IMF (International Monetary Fund) food price index, including cereals, meat, seafood, sugar, bananas and oranges [20]. The factors influencing the prices of agricultural products are also discussed. In this context it is justified to take into account natural conditions such as weather conditions. Of course, prices are largely influenced by factors such as unforeseen droughts, floods and diseases. Therefore, forecasting prices of agricultural products is a difficult subject, as the above mentioned factors should be taken into account in modelling [23].

One of the key differences between research aimed at assessing the factors influencing structural change in agriculture is the use of data in macro or micro scale. Analyses using information on the structure of the agricultural market (e.g. number of entities) at regional or national level, try to explain the dynamics of development over a certain period of time [9, 18]. Meanwhile, studies based on micro scale data use information at the level of agricultural commercial entities to explain structural changes e.g. changes connected to an increase in the number of such entities [8, 39].

The assessment of the impact of purchase and wholesale of milk on the agricultural market, which significantly affects the competitiveness of the country, is a very important element. It should be noted that there are no perfect, universally accepted tools to analyze the impact of purchase and wholesale of milk on the prices of milk on the market. The literature contains opinions of experts who do not consider this indicator to be important for assessing economic competitiveness. Such studies include Krugman, Dicken, Baldwin [4], who emphasize that the basic measure of economic competitiveness between countries is labor productivity, arguing that the increase in living standards is essentially equal to national productivity growth rates [4, 15, 27]. In studies on the influence of various factors on the condition of the agricultural market, the *Dynamic Stochastic General Equilibrium* (DSGE) models are popular [6]. The use of models of this type offers a chance for a relatively accurate picture of the correlations existing in the economy. These models can also simulate the effects of different driving forces, including economic policy instruments [40, 42]. Market equilibrium assumes a balance between supply and demand. For example, an increase in supply affects the equilibrium point, causing prices to fall. When there is an increase in the volume of supply (excess of goods), a fall in prices occurs, which in turn makes the market return to the situation where the original volume of supplied goods is sufficient [7, 21]. Therefore, it was decided to find another way of modelling change in the volume of wholesale deliveries of milk affecting its price in order to describe this phenomenon accurately. Bapna and others [5] have used regression modelling in their research on price dynamics at Internet auctions. Wohlgenant and others [44] introduced a new model of retail price range, which takes into account both changes in supply of produce and retail demand. They applied this model to beef prices. The aim of Popescu's work [33] was to select the best regression model to evaluate milk production. The study used milk production as a dependent variable of Y and dairy cattle population as an independent variable X. Two polynomial regression models were tested: linear regression and square regression.

Structural changes in agriculture are complex processes influenced by many factors external and internal with respect to the farm. Their source of these factors is the changes taking place in the allocation of resources, i.e. labor, land and capital. One of the factors influencing structural change is agricultural policy. It is a form of planned interference of state institutions in the economic system resulting from the belief in market imperfection. The Common Agricultural Policy (CAP) is an example of action whereby changes in the agri-food sector and rural areas are stimulated with public funds [43].

According to the models of attraction to a given agricultural specialization used in the literature, three different model specifications can be distinguished: simple effects, differential effects and a fully extended model. A simple effect model assumes the same effect of a given explanatory variable on market share of all considered groups of farms. For example, the price of cereals has the same marginal impact on the share of dairy and cereal farms. The differential model allows for the influence of explanatory variables to be different depending on market shares of groups of farms. For example, the price of cereals may have a different influence on shares of dairy farms than on shares of cereal farms. In the fully extended model, the effects of explanatory variables on the own farm group and cross-farm group may differ between equations for the farm share. This approach allows to analyze the influence of explanatory variables e.g. the number of entities observed in one group of farms on the shares of other groups of farms e.g. dairy farms, farms with permanent crops [10, 30].

The specificity of the agricultural market, similarly to the housing market, makes it difficult to choose appropriate models to describe the market. In the case of the housing market customer preferences should be measured using the hedonic method [46].

Agricultural economics supports the decision-making process in agricultural policy-making by providing concepts, procedures and data to decision makers. The aim of quantitative analysis of agricultural policy is to examine its impact on a range of indicators at different levels of scale. For example, income, prices, farm size, productivity, factor allocation, production, welfare on a global, national, sectoral, regional or agricultural scale. An example that clearly shows the need for agricultural policy analysis and decision support is the 2003 reform of the European Union's Common Agricultural Policy. The Common Agricultural Policy is characterized by a significant change in the production support system [3, 14]. For this purpose, statistical techniques of designing experiments and modelling are used [24, 28]. This particular approach allows to systematically carry out simulation experiments with different collections of input parameters in order to discover the relationship between the model input data and the corresponding output data. The input data reflect the key factors of structural changes, including technological changes and macroeconomic framework conditions [25, 26].

**The aim of this work is to analyze trends in order to obtain characteristics of changes in the volume of deliveries and the number of wholesale suppliers of milk within a few years from the introduction of the common agricultural policy.**

## MATERIALS AND METHODS

The analysis was performed by means of regression modelling using non-linear functions. The results of milk production from the years 2004–2011 were used in the research. The scope of the work included obtaining and proper grouping of the results, analysis of the obtained results by means of regression modelling, selection of an optimal model of the regression function, analysis of the generated models and interpretation of the results. The data for the research were obtained from the body governing the milk production quota mechanism. Data from 2004–2011 were used for the research. The number of producers (wholesale suppliers) and the volume of milk delivered by them to purchasing entities in the years 2004–2011 were used for the research. Data from each region in Poland were used for the research, taking into account the national average. In total, data from 16 voivodeships were used for the analysis. Then a comparative analysis of individual voivodeships to the national average was made. After analysis, empirical data were grouped and averaged. The analysis of the volume of wholesale sales by wholesale suppliers to purchasing entities was performed.

The obtained and grouped data were subjected to statistical analysis, during which the arithmetic mean, variance and standard deviation were determined. The data were then subjected to regression using exponential and power functions to determine the upward and downward trend and its character. The regression process was carried out in the MATLAB environment using the "fit" function, which uses the function of least squares to calculate the regression model parameters. The least squares method (LSM) is one of the most popular calculation methods used in statistics. It consists in determining the regression line, also called the trend line for the collected data – observable data, also called empirical data. The LSM method can be used to estimate both linear and non-linear relationships, however, in our case, non-linear relationships were used. In particular, four models of mathematical functions were used in the regression process: 1. $Fexp_1$ (1), which consists of the product of an exponential function with the exponent being the product of the parameter b and the independent variable (time t) and parameter a, which defines the amplitude; 2. $Fexp_2$ (2), which consists of the sum of two $Fexp_1$ functions, while the parameters of these functions being the regression coefficients determined in the regression process; 3. $Fpower_1$ (3), which is the product of the power function whose base is the independent variable i.e. time t and exponent is parameter b, and parameter a which defines the amplitude; $Fpower_2$ (4), which consists of the sum of the Fpower1 function and parameter c.

$$Fexp_1 = a * exp^{(bt)} \quad (1)$$

$$Fexp_2 = a * exp^{(bt)} + c * exp^{(dt)} \quad (2)$$

$$Fpower_1 = a * t^{(b)} \quad (3)$$

$$Fpower_2 = a * t^{(b)} + c \quad (4)$$

Where: a, b, c, d – are model parameters (regression coefficients),
t – independent variable [time].

The LSM method is designed to fit to the observable data collected, the pairs of results obtained for the applied correlations that are best matched to them (by calculation). The mathematical models were selected in such a way that it was possible to match their parameters with empirical data. The parameters of the model (a, b, c, d) were fitted in the regression process in such a way as to obtain possibly small fitting errors. The quality of the matching of measurement (empirical) data with the model (regression function) was determined by the size of the coefficient of determination $R^2$ (7) SSE sum of squared errors (5) root mean square error RMSE (8). It should be noted that an ideal match occurs when the value of $R^2$ is 1, while the values of SSE and RMSE are 0.

$$SSE = \sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \quad (5)$$

$$SST = \sum_{i=1}^{n}(y_i - \bar{y})^2 \quad (6)$$

gdzie: $n$ – is the number of observations,
$y_i$ – i-th observation,
$\hat{y}_i$ – i-th prediction (calculated value),
$\bar{y}$ – mean over observations.

$$R^2 = 1 - \frac{SSE}{SST} \quad (7)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}} \quad (8)$$

The mean number of milk producers (wholesale suppliers) in the years 2004–2011 was used as observation data (dependent variable), which are summarized in Table 1. Subsequent years were used as an independent variable (time t).

**Table 1. Mean number of wholesale milk suppliers and volume of wholesale milk deliveries in Poland in 2004–2011**

**Tabela 1. Średnia liczba hurtowych dostawców mleka i wielkość hurtowych dostaw mleka w Polsce w latach 2004–2011**

| Years | Number of wholesale milk suppliers | Wholesale supplies (kg) |
|---|---|---|
| 2004 | 355246 | 8 346 602 807 |
| 2005 | 294468 | 8 931 767 093 |
| 2006 | 279257 | 8 967 395 692 |
| 2007 | 246720 | 8 878 812 386 |
| 2008 | 200995 | 9 316 352 490 |
| 2009 | 182836 | 9 087 608 502 |
| 2010 | 170106 | 9 108 491 821 |
| 2011 | 157684 | 9 499 434 521 |

**Source:** Own study
**Źródło:** Opracowanie własne

## ANALYSIS AND DISCUSSION OF RESULTS

On the basis of the obtained results, comparative graphs of the number of suppliers and the volume of wholesale milk deliveries in Poland in the years 2004–2011 have been drawn up, which are presented in Figure 1. From the inclination of the trend in the figure at the top one can observe an exponentially decreasing number of wholesale suppliers in the years 2004–2011. At the same time the figure at the bottom shows an inversely correlated power increase of wholesale deliveries in the country.

Figure 2 shows the changes in the number of wholesale suppliers in subsequent years with the result of fitting four regression models. From the inclination of the trend in the figure we can observe an almost linear decline of wholesale suppliers in the country.

A summary report of the quality assessment of the fitting of mathematical models for the whole country is presented in Fig. 3. The model selection was based on three quality assessment measures: $R^2$, SSE and RMSE. For all the models, high values of $R^2$ were obtained, with values below 0.98 only for Fpower1. RMSE and SSE values for Fexp1, Fexp2 and Fpower2 models show values at a similar level, i.e. RMSE in the range from 10.0 to 10.5 and SSE in the range from 445 to 605, whereas for Fpower1 the RMSE value is almost twice as high and SSE value five times as high. On the basis of the data presented in Figure 3, it can be concluded that the best fitting to empirical data was obtained for the Fexp2 model.

Figure 4 shows the values of quality assessment coefficients for model fitting obtained for individual regions. On the basis of the bars whose colors correspond to the individual regions, it can be concluded that the regression models used do not achieve a good fit for all cases. In particular, when considering SSE values, significant differences in the results obtained for data from individual regions are visible. Especially for the Fpower1 model the mean value of an SSE is 29.42, while the median value is 2.27, which is due to the many times higher value of SSE for Lublin and Warsaw regions. Similarly, for the RMSE ratio the values for

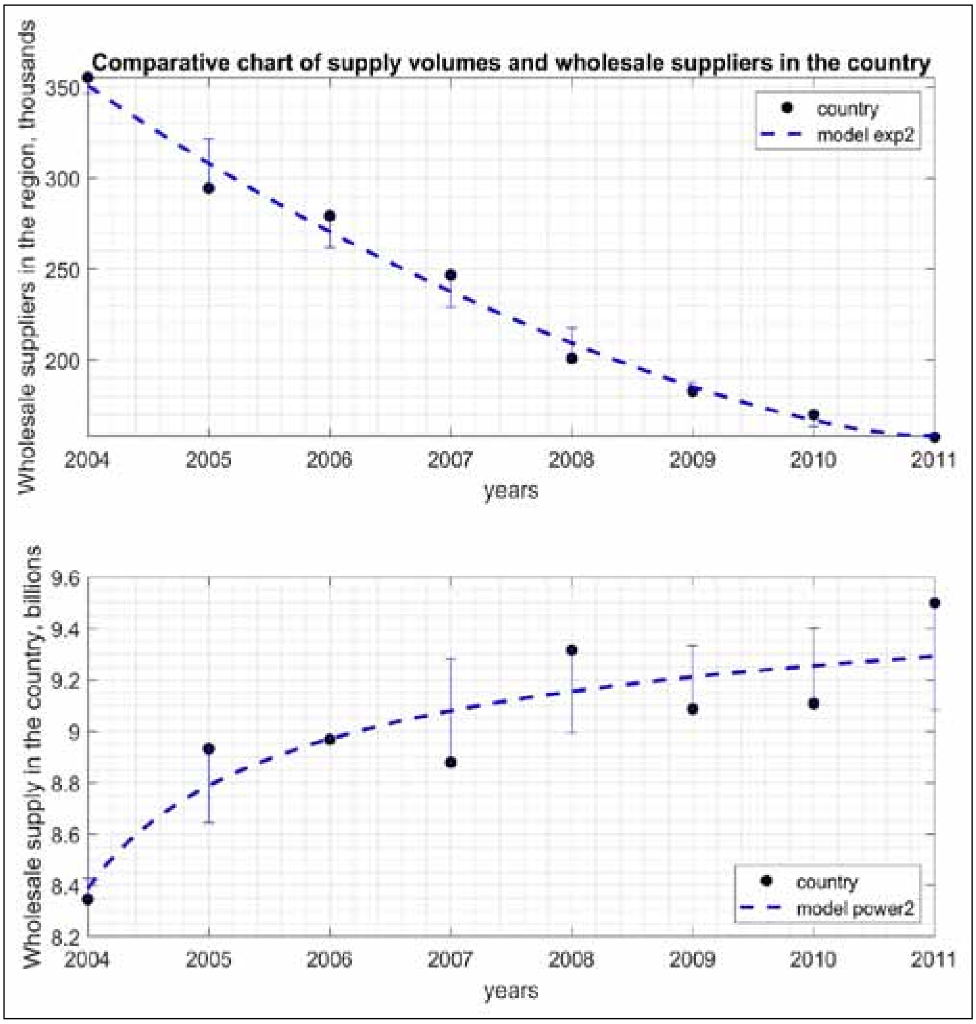


**Fig. 1. Comparative graphs of suppliers and wholesale supplies in the country.**
**Rys. 1. Wykresy porównawcze dostawców i dostaw hurtowych w kraju.**
**Source:** Own study
**Źródło:** Opracowanie własne

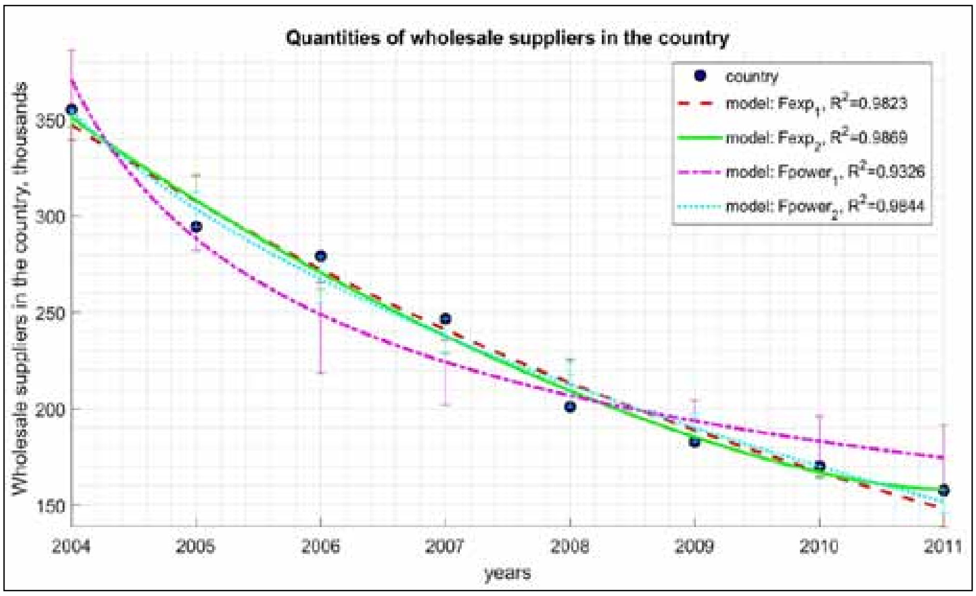


**Fig. 2. Changes in the number of wholesale suppliers in the country.**
**Rys. 2. Zmiany w ilości hurtowych dostawców w kraju.**
**Source:** Own study
**Źródło:** Opracowanie własne

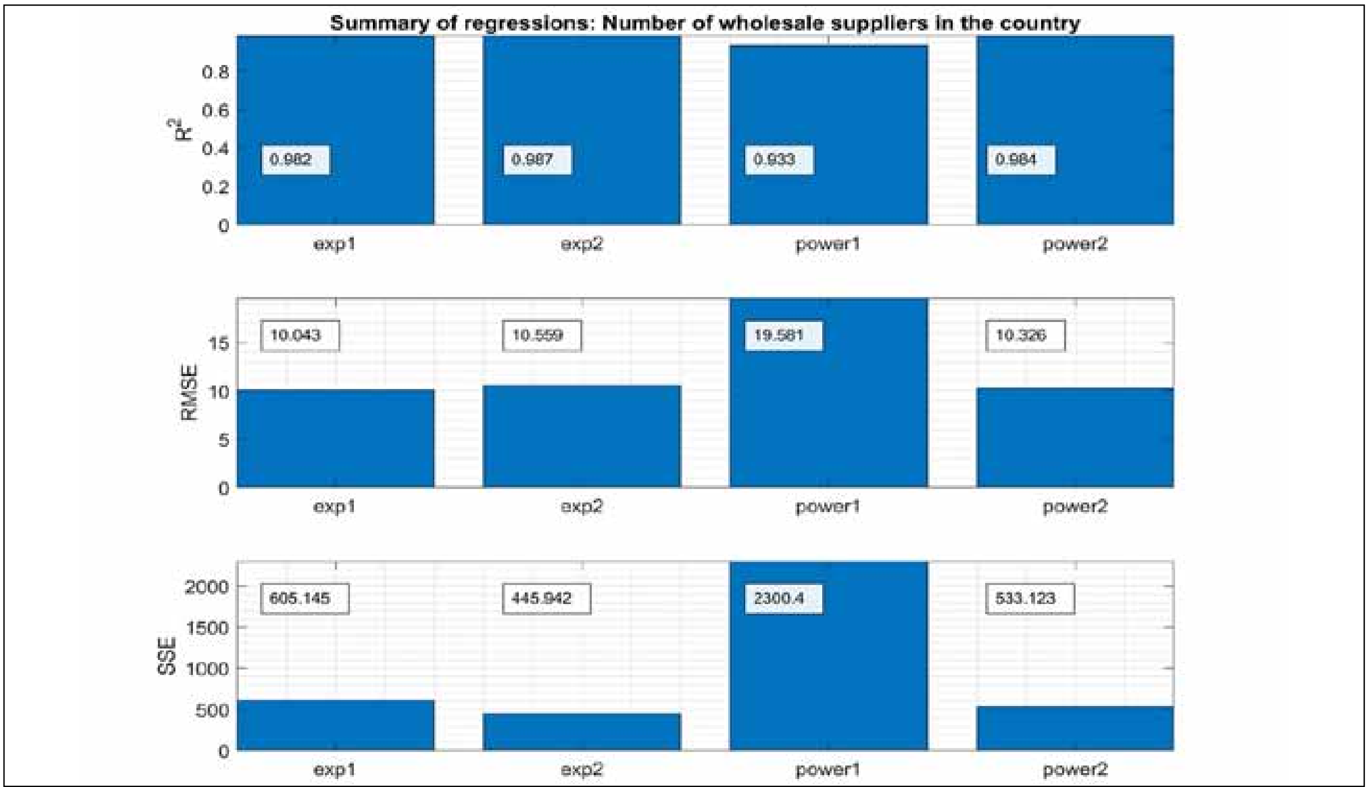


**Fig. 3. Summary of the quality assessment of the fitting of the number of wholesale suppliers in the country.**
**Rys. 3. Podsumowanie oceny jakości dopasowania liczby dostawców hurtowych w kraju.**

**Source:** Own study

**Źródło:** Opracowanie własne

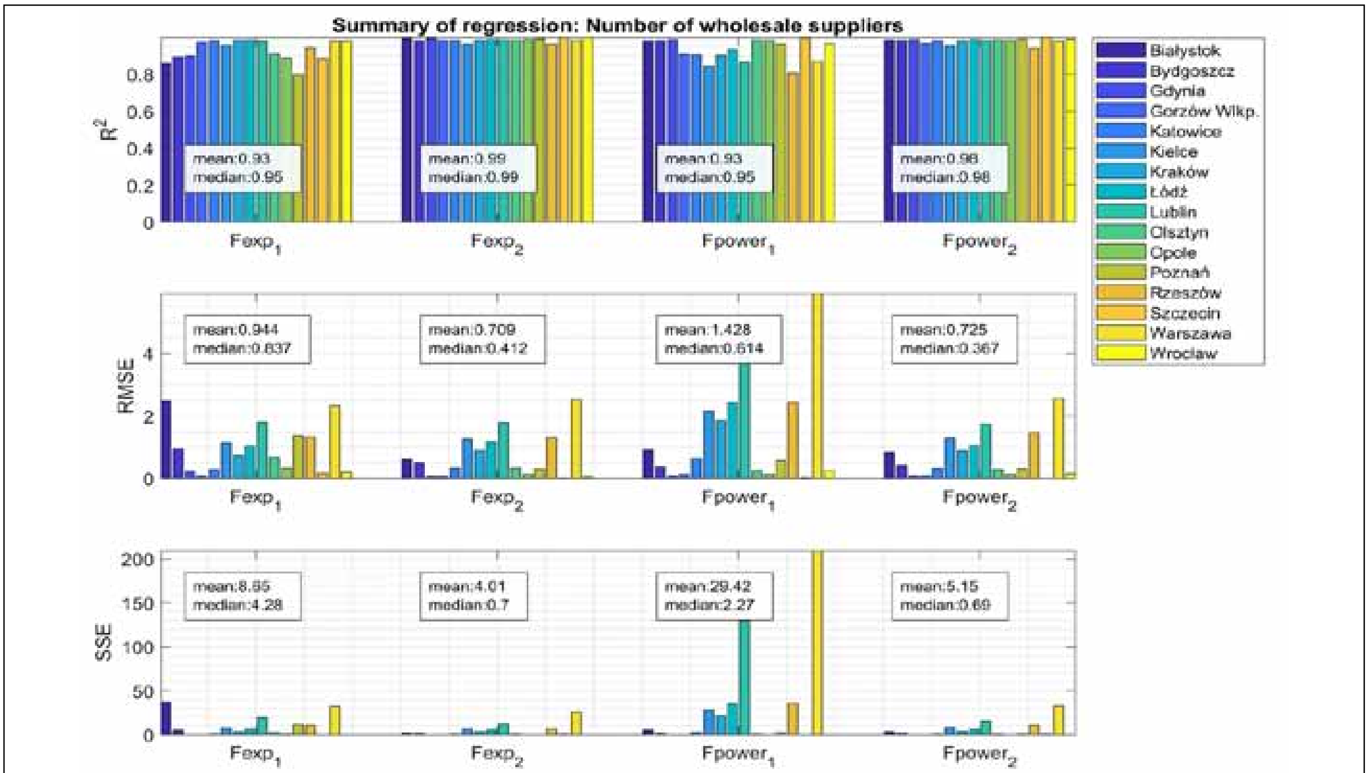


**Fig. 4. Summary of the results of the quality assessment analysis of the fitting of the number of wholesale suppliers in all regions, where colors symbolize data corresponding to individual regions.**
**Rys. 4. Podsumowanie wyników analizy oceny jakości dopasowania liczby dostawców hurtowych we wszystkich regionach, gdzie kolory symbolizują dane odpowiadające poszczególnym regionom.**

**Source:** Own study

**Źródło:** Opracowanie własne

these two regions are significantly higher. However, the analysis of $R^2$ values shows a high similarity in the quality of fit of the second order model, both power and exponential model, for which $R^2$ exceeds 0.98, both for the mean and median values. The other two models obtain slightly worse values of $R^2$, which exceed 0.9. Taking into account all values of calculated coefficients it can be concluded that the best fit was obtained for Fexp2 model.

Figure 5 shows the changes in the volume of wholesale deliveries in subsequent years with the result of fitting of four regression models. Unlike the number of wholesale suppliers, the volume of wholesale supplies in the country increased exponentially, which was confirmed by the fact that the best matching of observed data and the regression curve is for the Fpower2 model.

Figure 6 presents a summary of the results of the quality assessment analysis of the fitting of regression models for the whole country. The model was selected on the basis of three quality assessment measures: $R^2$, SSE and RMSE. For all models similar values of $R^2$ were obtained in the range from 0.691 to 0.793, SSE in the range from 0.169 to 0.251, RMSE in the range from 0.173 to 0.239. The second order power model, Fpower2, had the highest value of the $R^2$ coefficient and the lowest value of the SSE coefficient. It should be noted that for the first order power model, Fpower1, slightly better RMSE values were obtained compared to the second order power model.

Figure 7 shows the values of quality assessment coefficients for model fitting obtained for particular regions. On the basis of the bars whose colors correspond to the individual regions, it can be concluded that the regression models used do not achieve a good fit for all cases. In particular, for the regions of Gdynia, Gorzów, Katowice, Łódź, Opole and Szczecin, R2 values were obtained at the level below 0.6

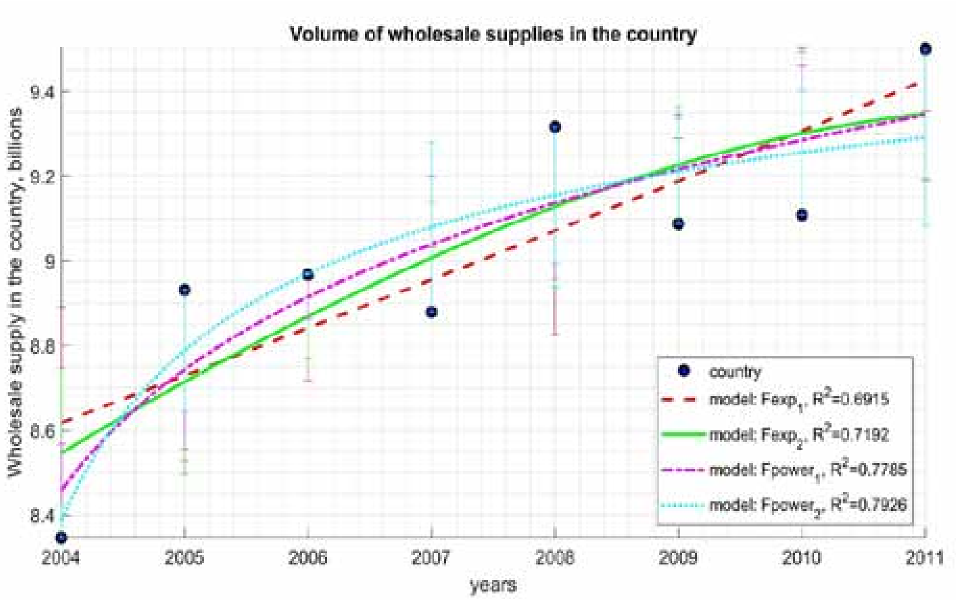


**Fig. 5. Changes in the volume of wholesale supplies in the country.**
**Rys. 5. Zmiany wielkości dostaw hurtowych w kraju.**
**Source:** Own study
**Źródło:** Opracowanie własne

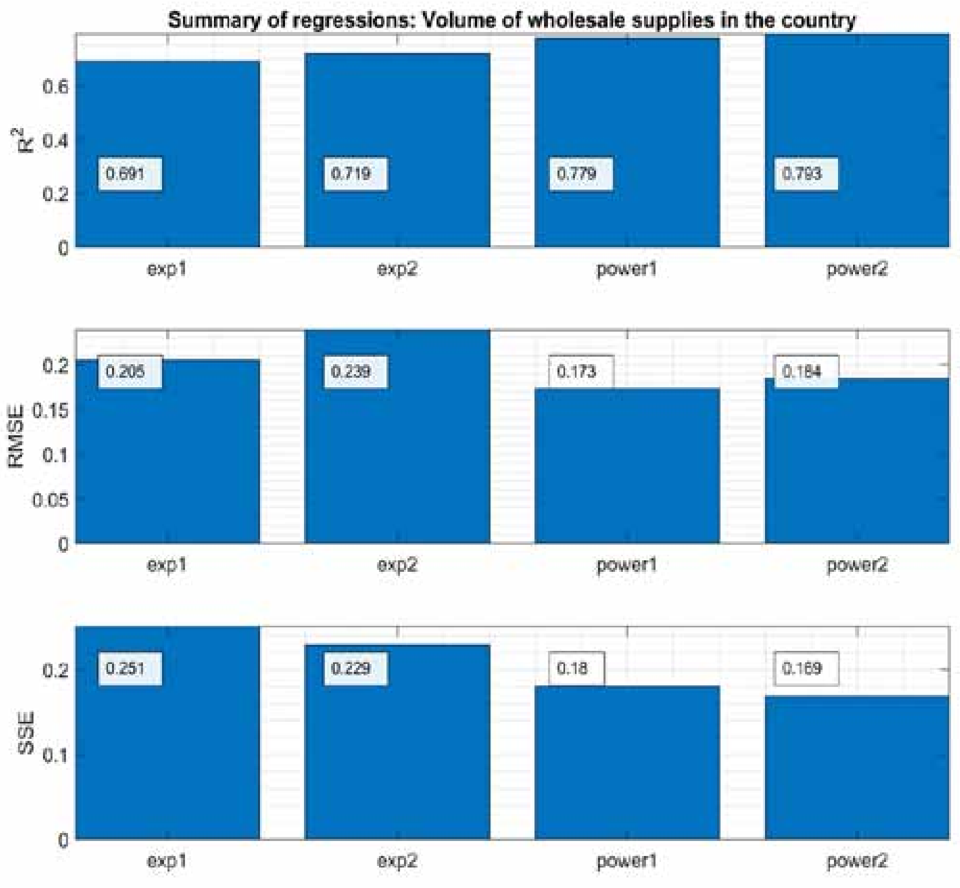


**Fig. 6. Summary of the results of the quality assessment analysis of fitting the volume of wholesale supplies in the country.**
**Rys. 6. Podsumowanie wyników analizy oceny jakości dopasowania wielkości dostaw hurtowych w kraju.**
**Source:** Own study
**Źródło:** Opracowanie własne

regardless of the model, with the exception of the Szczecin region, for which only for the Fexp2 model higher values were obtained, indicating a good fit. For the regions of Białystok, Bydgoszcz, Rzeszów, Kielce, Kraków and Poznań values of $R^2$ above 0.8 were obtained regardless of the model, except for the Fpower1 model, for which lower values of $R^2$ were obtained. The analysis of SSE coefficient values allowed to indicate differences in the fitting of regression models for data obtained in particular regions, especially differences for Warsaw region. However, it should also be noted that these differences are at the level of one thousandth of a fraction, which indicates that they are not significant. Based on the data presented in Figure 7, it can also be shown that higher values of $R^2$ do not always correlate with low values of SSE and RMSE, so it seems important to consider the quality of model matching on the basis of all three accuracy measures.

Popescu [33] in his research indicated the importance of comparative analysis of the standard error of different regression models, and finally decided to choose the type of regression whose standard error is the smallest, because the standard error is a measure of forecast accuracy. Authors managed to obtain a positive correlation of r = 0.884, the standard error of regression was smaller for linear regression, σest = 2 286.028830 than for square regression, σest = 2 336.915726, just in this case linear regression proved to fit the data better [33]. When describing the phenomenon of change in the volume of milk production depending on wholesale milk suppliers in particular regions of Poland, non-linear functions worked best. A satisfactory fit was obtained for power model of the second order, Fpower2, which was characterized by the best fit of $R^2$ = 0.987; RMSE = 10.559; and SSE = 445.942. In the modeling describing the volume of milk wholesale deliveries in the country, also the best fit was obtained for the power model of second order which was characterized by the quality factor: $R^2$ at 0.793; RMSE = 0.184 and SSE = 0.169. Empirical modelling (EM) is a useful approach to analyze different problems in many areas. As it is known, this type of modelling is particularly helpful when parametric models cannot be formulated for various reasons. Based on different methods and approaches (e.g. the least squares method), it provides a preliminary understanding of the relationships that exist between different variables belonging to a particular system or process [19]. The least squares method also allowed to obtain satisfactory results allowing to describe changes of production quantities and wholesale suppliers of milk on the agricultural market in Poland. In the research conducted by

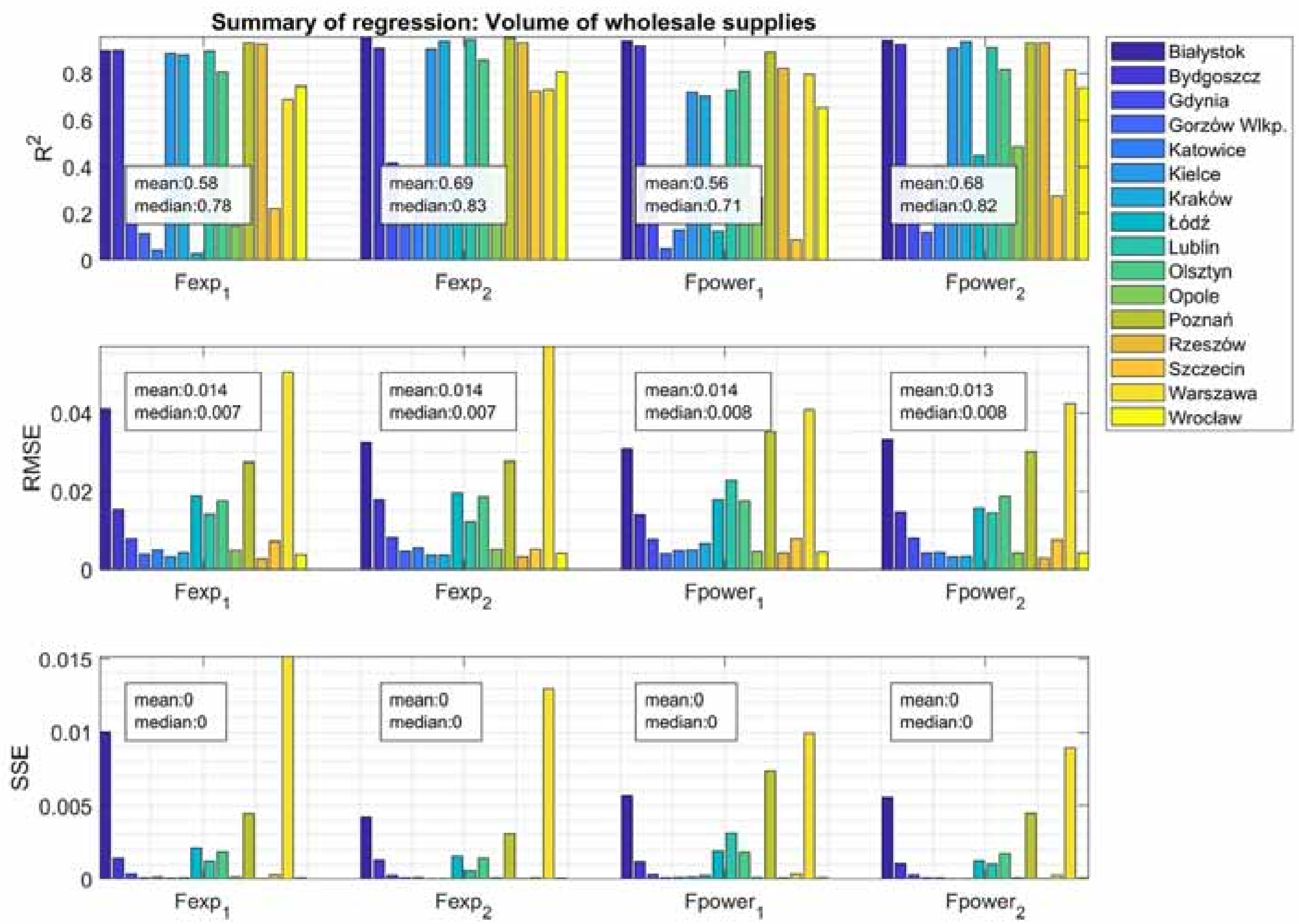


**Fig. 7. Summary of the results of the quality assessment analysis of wholesale supply fitting in all regions, where colors symbolize data corresponding to individual regions.**

**Rys. 7. Podsumowanie wyników analizy oceny jakości dopasowania zaopatrzenia hurtowego we wszystkich regionach, gdzie kolory symbolizują dane odpowiadające poszczególnym regionom.**

**Source:** Own study

**Źródło:** Opracowanie własne

Jaliliva et al. [22] a two-stage approach to the least squares analysis was applied to estimate the impact of contextual variables on rice production. Many scientific papers have proposed and studied the use of a partially adaptive estimation technique to improve the reliability of conclusions drawn from multiple regression models when the dependent variable is not a normal distribution [17, 41]. These results confirm the assumption that the application regression techniques in the description of changes in production volume and wholesale suppliers of milk on the agricultural market is justified, as proved by the revision of the proposed models by comparing the $R^2$ factor. The usefulness of this technique for agricultural economics research is assessed using Monte Carlo simulations and two main applications: time series analysis and empirical model [44]. Ramirez et al. [34] found that the least-squares method allows in practice for more precise conclusions about the magnitude of the influence of independent variables on the dependent variable of interest. Moreover, this technique generates confidence intervals for forecasts of dependent variables, which are more efficient and consistent with the observed data [18, 20]. Non-linear regression models are important tools, because many processes in agriculture are better represented by non-linear than linear models. The fitting of non-linear models is not a one-stage procedure, but a complex process that requires careful examination of each individual stage. Depending on the purpose and field of application, different priorities are set when fitting non-linear models; these include obtaining acceptable estimates of parameters and a good model fit while meeting the standard assumptions of statistical models [2]. The aim of the studies by Daud et al. [13] was to identify sources of risk that may occur in the existing milk supply chain and their impact on the production chain behavior. Agricultural production is in fact a business of risk. Risks exist at each stage of production conducted by each participant of the production chain. This means that the success of improving the results of agricultural activity will depend mainly on the ability of entities to manage risk [29, 34, 36, 45] Roder et al. [35] and Neuenfeldt et al. [31, 32], while they analyzed the impact of various socio-economic factors on changes in the specialization of farms on the basis of data at the farm level only. Recent studies also combine micro and macro data to make better use of available information when identifying and predicting structural changes in farms [37, 38]. The analysis of the obtained results also showed that regression modelling can be a useful tool for forecasting and explaining structural changes in agriculture. It should be noted here that on the territory of Poland the number of entities collecting milk has decreased while the amount of milk collected by these entities has increased. Therefore, it is noted that milk production is undergoing specialization by its concentration. Therefore, it can be clearly shown that the historical structure of farms explains the need to develop specialization of agricultural holdings. Dracha [16] in his research analyzed wheat, corn and soybean. Forecasts one month in advance were constructed using such techniques as dynamic model averaging (DMA), probability model median and Bayesian model averaging. Common features of these methods are the time-varying parameters of the approach to estimating regression coefficients and dealing with model uncertainty. The author started with many potentially important explanatory variables and constructed various linear regression models. Then, on the basis of these models he constructed an averaged forecast. Moreover, these techniques can be easily modified from model averaging to model selection approach. The interpretation of time-variable weights assigned to component models containing a given variable suggests that the economic development of emerging markets (Brazil, Russia, India and China) has recently been one of the most important drivers of agricultural goods prices. The analysis was conducted on monthly data between 1976 and 2016. The initial factors influencing the price were various fundamental, macroeconomic and financial factors [16]. Neunefeld et al. [31, 32] in their article analyzed the factors of structural change of farms in the EU-27, using a new analytical framework in the field of agricultural economics. They applied the model of multiplicative competitive interaction (MCI). The MCI offers a more economical specification for estimating models of shares of regional farm groups compared to the popular Markov approach. The MCI framework explains the shares of regional farm groups taken from the Farm Structure Survey (FSS) using socio-economic variables from the Farm Accountancy Data Network (FADN) and other databases from 1989 to 2013. The authors considered 8 production specializations and 2 classes of size at regional level NUTS 2. In addition, they conducted a simulation experiment in which they obtained the flexibility of structural changes in relation to time-dependent variables. The structural change seems to be the most flexible with respect to income and macroeconomic variables [31, 32]. Therefore, a deeper analysis of the results obtained also shows that some of the estimated coefficients suggest an unexplained response of farm specialization shares with respect to price. The reasons can partly be attributed to the peculiarities of the data set used. Agriculture is not a very dynamic segment of the economy. Therefore, the assumption of no changes or no business operation is confirmed by the observed time series [31, 32].

## CONCLUSIONS

On the basis of regressive modelling conducted in order to obtain characteristics of the influence of changes in the number of wholesale milk suppliers on milk production, it can be stated that regressive modelling and the use of the least squares function allows to generate models describing the phenomenon of tendencies of changes in the volume of milk production depending on the number of suppliers in particular regions of Poland. The best fit was obtained for exponential model of the second order, which was characterized by the coefficient $R^2$ = 0.987; RMSE = 10.559; SEE = 445.942. Regressive modelling and the use of the least squares function allows also to generate models describing the volume of wholesale milk deliveries in Poland. The best fit was obtained for the power model of the second order, which had the following values for the quality factors under consideration: $R^2$= 0.793; RMSE = 0.184 and SSE = 0.169. The analysis of the empirical data showed that the volume of milk delivered in the country increased within 8 years while the number of wholesale suppliers decreased. These results reflect the decreasing number of farms maintaining dairy cattle in Poland due to abandonment of commercial milk production in small farms in favor of farms specialized in this sector. It should be noted that changes in the concentration of production have a significant impact on the quality of the raw material and products due to its professional specialization. This, in turn, increases the competitiveness of our production on the EU market.

## WNIOSKI

Na podstawie modelowania regresywnego przeprowadzonego w celu uzyskania charakterystyk wpływu zmian liczby dostawców hurtowych mleka na produkcję mleka można stwierdzić, że modelowanie regresywne oraz wykorzystanie funkcji najmniejszych kwadratów pozwala na generowanie modeli opisujących zjawisko tendencji zmian wielkości produkcji mleka w zależności od liczby dostawców w poszczególnych regionach Polski. Najlepsze dopasowanie uzyskano dla modelu wykładniczego drugiego rzędu, który charakteryzował się współczynnikiem R2 = 0,987; RMSE = 10,559; ZOBACZ = 445.942. Modelowanie regresywne i wykorzystanie funkcji najmniejszych kwadratów pozwala również na generowanie modeli opisujących wielkość hurtowych dostaw mleka w Polsce. Najlepsze dopasowanie uzyskano dla modelu potęgowego drugiego rzędu, który dla rozważanych współczynników jakości miał następujące wartości: R2= 0,793; RMSE = 0,184 i SSE = 0,169. Analiza danych empirycznych wykazała, że ilość dostarczonego mleka w kraju wzrosła w ciągu 8 lat, natomiast zmniejszyła się liczba dostawców hurtowych. Wyniki te odzwierciedlają zmniejszającą się liczbę gospodarstw utrzymujących bydło mleczne w Polsce w związku z zaniechaniem towarowej produkcji mleka w gospodarstwach małych na rzecz gospodarstw wyspecjalizowanych w tym sektorze. Należy zauważyć, że zmiany w koncentracji produkcji mają istotny wpływ na jakość surowca i produktów ze względu na jego specjalizację zawodową. To z kolei zwiększa konkurencyjność naszej produkcji na rynku UE.

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