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Econometric Analysis of Pork Meat Supply-Demand Relations in the Czech Republic

Diploma Thesis

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DIPLOMA THESIS ASSIGNMENT

Nikol Boháčková

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Econometric Analysis of Pork Meat Supply-Demand Relations in the Czech Republic

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Objectives of thesis

The aim of the diploma thesis is to determine and to evaluate supply-demand relations at Pork Meat Market in the Czech Republic in the selected period.

The aim will be fulfilled based on the partial aims. Then, several hypotheses will be defined and verified. Based on the results of and empirical analysis the final conclusions will be introduced.

Methodology

The diploma thesis will cover both theoretical and empirical part. Theoretical part will contain theoretical background of the selected topic as well as the methodological framework. Scientific literature will be used to prepare the literature overview. The empirical analysis will be based mainly on the econometric analysis of the time series analysis. Other suitable methods will be employed as well. Based on the empirical analysis the results will be presented and some recommendations will be suggested.

The proposed extent of the thesis

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Keywords

Supply, demand, pork meat, time series, econometric model.

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Declaration

I hereby declare that I have worked on this thesis "Econometric Analysis of Pork Meat Supply-Demand Relations in the Czech Republic" by myself under the guidance of the supervisor of this diploma thesis and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any third person.

In Prague, on 7th April 2020 …... …………………

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Econometric Analysis of Pork Meat Supply-Demand Relations in the Czech Republic

Ekonometrickí analýza nabídkovo-poptávkových vztahů vepřového masa v České republice

Summary

The aim of the diploma thesis is to determine and to evaluate supply-demand relations at Pork Meat Market in the Czech Republic in the selected period (2000-2018). The aim was fulfilled based on the partial aims. Those are to identify and verify factors, which may influence the consumption and consumer price of pork. Then, several hypotheses were defined and verified.

The diploma thesis is covered by both theoretical and empirical part. Theoretical part contains theoretical background of the selected topic as well as the methodological framework, description of consumer behaviour on the market dealing specifically with consumption of a pork meat and its demand, and furthermore, econometric background overview necessary to establish the second part of the thesis. Scientific literature was used to prepare the literature overview. The empirical analysis was based mainly on the econometric analysis of the time series analysis. Other suitable methods were employed as well. Secondary data from CSO were used for calculations. Based on the empirical analysis the results were presented and some recommendations suggested.

Keywords: supply, demand, domestic pigs, pork meat, time series, econometric model, consumption

Souhrn

Cílem diplomové práce je zjistit a zhodnotit vztahy nabídky a poptávky na trhu s vepřovým masem v České republice ve vybraném období (2000–2018). Cíl byl naplněn na základě dílčích cílů. Zejména se jedná se o identifikaci a ověření faktorů, které mohou ovlivnit spotřebu a spotřebitelskou cenu vepřového masa. Poté bylo definováno a ověřeno několik hypotéz.

Diplomová práce zahrnuje teoretickou i empirickou část. Teoretická část obsahuje teoretické základy vybraného tématu a metodický rámec, popis chování spotřebitele na trhu, který se konkrétně zabývá spotřebou vepřového masa a jeho poptávky, a dále ekonometrický přehled, který je nezbytný pro vytvoření druhé části práce. K přípravě literární rešerše byla použita odborná literatura. Empirická analýza byla založena zejména na ekonometrické analýze analýzy časových řad. Jiné vhodné metody byly také použity. K výpočtům byla použita sekundární data z ČSU. Na základě empirické analýzy budou prezentovány výsledky a navrhnuta některá doporučení.

Klíčová slova: nabídka, poptávka, prase domácí, vepřové maso, časové řady, ekonometrický model, spotřeba

Contents

1 **Introduction** ... 5

2 **Objectives and Methodology** ... 6

2.1 Objectives ... 6

2.2 Methodology ... 6

3 **Theoretical Part** ... 16

3.1 Market and its functions ... 16

3.1.1 Supply and Demand ... 19

3.2 Consumer behaviour ... 21

3.2.1 Cardinal Approach ... 21

3.2.2 Ordinal Approach ... 22

3.2.3 Substitutes and Complements ... 24

3.2.4 Other Perspectives ... 24

3.3 Domestic Pig ... 26

3.3.1 Breeds of Pigs ... 27

3.3.2 Feeding ... 28

3.3.3 Pig Farming ... 29

3.3.4 Lifecycle of Pigs ... 30

3.3.5 Pork meat ... 32

3.3.6 SEUROP system ... 37

3.4 Econometric Modelling ... 40

3.4.1 Construction of Econometric model ... 41

3.4.2 Economic Theory and Model ... 41

3.4.3 Econometric model ... 43

3.4.4 Linear Regression Model (LRM) ... 44

3.4.5 Mathematical form of model and its equations ... 47

3.4.6 Data ... 48

3.4.7 Trend of Time Series ... 50

3.4.8 Multicollinearity ... 51

3.4.9 Parameter Estimation ... 53

3.4.10 Model verification ... 54

3.4.11 Model Application ... 56

4 **Practical part** ... 57

4.1 Development of Time Series ... 57

4.2 One equation model ... 65

4.2.1 Economic model ... 65

4.2.2 Econometric model ... 69

4.2.3 Data ... 71
4.2.4 Parameters' Estimation (using OLSM in Gretl SW) ... 74
4.2.5 Model verification ... 76
4.2.6 Model application ... 84
4.3 Multiple-equations model ... 87
4.3.1 Economic model ... 87
4.3.2 Econometric model ... 88
4.3.3 Data ... 88
4.3.4 Model identification ... 91
4.3.5 Parameters' estimation using TSLSM in SW Gretl ... 92
4.3.6 Model verification ... 93
4.3.7 Matrix B, Γ and matrix M ... 100
4.3.8 Model application ... 102
4.4 One equation model ... 104
4.4.1 Economic model ... 105
4.4.2 Econometric model ... 106
4.4.3 Data ... 107
4.4.4 Parameters' Estimation (using OLSM in Gretl SW) ... 109
4.4.5 Model verification ... 109
4.4.6 Model application ... 114
5 Conclusion ... 117
6 Bibliography ... 120
7 List of Figures, Tables and Pictures ... 125
8 Appendix ... 126

1 Introduction

The consumption creates a major part of our lives. We consume goods and services on the daily basis even without noticing or being aware of this fact. The approach of us, consumers, has changed in the beginning of 20th century. We do not consume because it is a necessity anymore, but the want is the main reason that drive our consumption.

Thanks to the globalization across the world, it became easier to buy goods or services from anywhere around it. The competition on the market increased. The producers attract us with different methods, whether is a lowering of the prices, the high quality of the product or services advertising or just very attractive promotions, nowadays, mainly on social media.

Nevertheless, some products do not need promotion. Such as basic items from the grocery, our cuisine cannot lack – such as a meat. Meat is very important for our nutrition. Consumers prefer different kinds and types according to different ages, genders, tradition, culture, nutritional needs based on lifestyles or health condition or restrictions, budget constraints, education and others. Meat is consumed by greater part of the present population in the Czech Republic. Especially pork is indispensable in the Czech Republic as it is a basis for traditional Czech cuisine. The price is low and therefore is one of the most favourite meat in Czech households and restaurants.

The preferences and choice are developing and changing, following different trends, during the time. Even if we compare the meat consumption from the historical point of view, it was rather a rare event. Today it is considered normal to eat a meat at least once a day. By meat consumption lot of people imagine the steak from one of the meat kinds and do not realize, the other times the meat is consumed in various forms of products as a ham or pate for example as those are not percept as a meat piece.

This work determines and evaluates the role of price and role of other influences in relation to one of the most consumed kinds of meat, the pork meat, in the Czech Republic on the microeconomic level.

2 Objectives and Methodology

2.1 Objectives

The aim of the diploma thesis is to determine and to evaluate supply-demand relations at Pork Meat Market in the Czech Republic, in the selected period (2000-2018).

The objectives will be fulfilled based on the partial aims. Those are to identify and verify factors, which may influence the consumption and consumer price of pork:

1. Explanation of determinant of pork meat consumption and its prices
2. Description of pork meat consumption development and the forecast for years 2019 and 2020
3. Evaluation of impact of chosen variables on pork meat consumption and its consumer price based on regression analysis
4. Simulation of scenarios and ex-post prognosis
5. Synthesis of results and following evaluation of consumption of pork in the Czech Republic

Then, the assumptions were stated with several hypotheses that were defined and are going to be verified that are introduced in chapters *4.2*, *4.3* and *4.4* of the empirical part, dealing with individual models of those section. Based on the results of and empirical analysis the final conclusions will be introduced.

2.2 Methodology

The diploma thesis will cover both theoretical and empirical part. Theoretical part will contain theoretical background of the selected topic as well as the methodological framework, description of consumer behaviour on the market dealing specifically with consumption of a pork meat and its demand, and furthermore, econometric background overview necessary to establish the second part of the thesis. Scientific literature, research papers and internet sources are going to be used to prepare the literature overview.

Secondary data will be used for analysis of S-D relations at pork meat market in the Czech Republic. The entry data are obtained from the Czech Statistical Office (CSO) web page. Annual period was selected based on the methodology of the Czech Statistical Office as the records of consumption are in annual period for the first years and therefore the nineteen observations from the year 2000 to 2018 are going to be used. The data on consumption for the year 2019 are not available yet and therefore, were not included to the thesis. Data are going to be systematized for further calculations and processing in software Gretl and MS Excel

The empirical analysis will be based mainly on the econometric analysis of the time series. The relationship among selected variables is going to be investigated using ordinary least square method or two-staged least square method due to the model type. Other suitable methods will be employed as well. This part is going to utilize the Gretel software.

In the first phase of practical part the development of meat consumption individually for the mainly consumed kinds of meats and as whole, the development of prices of pork is going to be evaluate based on elemental characteristics of time series. Time series of meat consumption is going to be appointed by the most suitable trend functions. Based on that, the the forecast of for the years 2019 and 2020 is going to be elaborated by extrapolation. This part of the work is going to be processed in Microsoft Excel.

Based on the empirical analysis the results will be presented and some recommendations will be suggested.

Trend of Time-Series

$$\boldsymbol{y_t = f(t, u_t)}$$

Where:

$\boldsymbol{y_t}$…is the value of indicator during the time t (t = 1, 2, …, n)
$\boldsymbol{u_t}$ …is a value of random component in time t.

Green (2003)

Trend functions

Hušek (1995) distinguish four types of trend functions:

a. Linear function – is used when the absolute growth of annual changes of the individual variable are approximately constant

$$T_t = \beta_0 + \beta_1 t$$

b. Power function – is used in case there are increasing annual growths in geometrical series development

$$T_t = \beta_0 \, t^{\beta_1}$$

c. Quadratic function – is applied for expression of basic changes in the development when positive increments turn into negative ones and vice versa

$$T_t = \beta_0 + \beta_1 t + \beta_1 t^2$$

d. Hyperbolic function – is chosen when the trend of time series is asymptotically getting to the constant value from above or below

There are also:

e. Logarithmic function

$$T_t = \beta_0 + \beta_1 log\, t$$

f. Exponential function

$$T_t = \beta_0 + \beta^t$$

g. Logistic function

$$T_t = \frac{k}{1 + e^{\beta_0 \beta_1 t}}$$

Where:

β_0, β_1 …are structural parameters of the trend function

t …is the time (t = 1,2,3… n)

Estimation of Parameters

OLS method minimizes residual variance components and is described as minimization by Gujarati (2002) with formula below:

$$\boldsymbol{min \sum u_t^2 = \sum (y_t - \hat{y}_t)^2}$$

Where:

$\boldsymbol{u_t}$…is residual

$\boldsymbol{y_t}$….is real value of explained variable

$\boldsymbol{\hat{y}_t}$…is the estimated value of explained variable

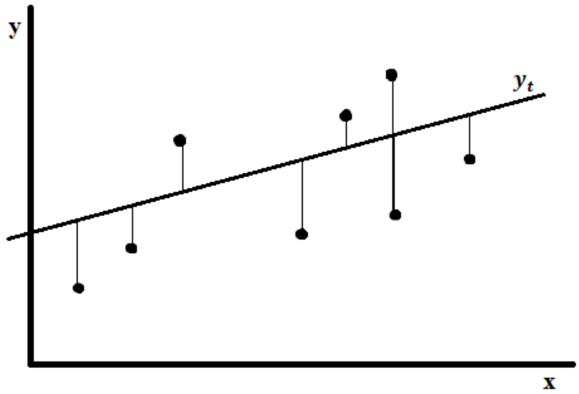
However, the formula of OLSM is:

$$\boldsymbol{\gamma = (X^T * X)^{-1} * X^T * Y}$$

Where:

$\boldsymbol{\gamma}$…is a vector of estimated parameters of k*1 size
$\boldsymbol{X}$…is matrix of statistical data (predetermined variables) of n*k size
$\boldsymbol{X^T}$…is transposed matrix X
$\boldsymbol{Y}$…is vector of endogenous variables (real values) of n*1 size

Picture 1: OLSM graphical depiction



Source: Gujarati (2002), own elaboration

OLSM can be applied for simple and recursive models. For parameters estimation of simultaneous models, the OLSM can be only applied when every equation in the model is exactly identified. Identification should be performed for each equation individually using the formula:

$$\boldsymbol{k} ** \geq \boldsymbol{g}\,\Delta - \boldsymbol{1}$$

Where:

k…represents the number of predetermined variables in the whole model
g…presents the number of endogenous variables in the whole model
*****, **Δ,** or **v**…means that the variable is included in the identified equation
******, **ΔΔ**, or **n**…means that the variable in the equation for which identification is performed is not included, but is contained in other model equations

If there is a sharp inequality, the equation is over-identified. When the equality occurs, the equation is exactly identified. Finally, in case that inequality does not apply, the equation is not identified. (Gujarati 2010)

In the first stage of TLSM the matrix of real values Y is substituted by matrix of theoretical values Ŷ. There are values, estimated by regression of all predetermined variables in the model or in another words, the theoretical values of endogenous variables of the equation are estimated. Explaining variables correlated with random component are being substituted by non-stochastic values. This fulfils the assumption for the application of the Ordinary least squares' method for the actual estimation of structural parameters for the second stage of TLSM and the Reduced form of equations is formed. The formula for the first step is:

$$\boldsymbol{\hat{Y}_2 = X(X^T X)^{-1} X^T Y_2}$$

Where:

$\boldsymbol{\hat{Y}_2}$…is matrix of theoretical values

$\boldsymbol{Y_2}$…matrix of endogenous variables

X = [X*, X]** matrix of all predetermined variables in the model

X*…matrix of values of predetermined variables included in estimated equation

X**…matrix of predetermined variables excluded from the estimated equation but included in other equations of the model

In the second stage of TLSM the vector of structural parameters of the estimated equation is calculated from the relation:

$$\begin{bmatrix} \boldsymbol{\beta_2} \\ \boldsymbol{\gamma_{1*}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\hat{Y}_2^T \hat{Y}_2} & \boldsymbol{Y_2^T X_*} \\ \boldsymbol{X_*^T Y_2} & \boldsymbol{X_*^T X_*} \end{bmatrix}^{-1} \begin{bmatrix} \boldsymbol{\hat{Y}_2^T} \\ \boldsymbol{X_*^T} \end{bmatrix} \boldsymbol{y_1}$$

The calculated parameters in the resulting vector are in following order: Firstly, there are parameters of the endogenous variables in the order in how the variable values enter the matrix Y_2. Then, there are parameters of predetermined variables in the order how they were included in the matrix X*.

The results are testes by the same procedure as in OLSM except in the statistical testing, where instead of $(X^T X)^{-1}$ matrix the covariance matrix is used. The covariance matrix is the first of two sub matrices in TLS method. (Čechura et al., 2017)

Statistical verification

In the statistical verification, we use statistical tests to check if the estimated parameters are statistically significant (Gama) and test the goodness of fit is also done. The statistical verification can be calculated in Microsoft Excel software but the Gretl software provides the outputs of this verification as well.

To test if the influence if explanatory variable influences explained variable the ***t-test*** is used for every single parameter. This procedure is composed of steps presented below.

Firstly, the null and alternative ***hypotheses*** are stated (H_0: $\gamma = 0$ and H_1:$\gamma \neq 0$).

As a second step, the ***Adjusted Residual Sum of Squares*** (*RSS with bar*) also representing *Variance of residuals* S_u^2 is calculated:

$$\overline{\boldsymbol{RSS}} = \frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{n-p}$$

Where:

y_t…are real values

$\hat{y}_t$…are theoretical values

In a third step, the *inverse matrix* X^{-1} is needed, especially its leading diagonal. The individual values of this Covariance matrix are multiplied by Residual sum of squares and by this calculation, the ***Variance of estimated parameters*** is obtained.

$$s_{ii} = \overline{RSS} * (X^T X)^{-1} \begin{bmatrix} s_{11} & \cdots & \\ \vdots & \ddots & \vdots \\ & \cdots & s_{ii} \end{bmatrix}$$

In a fourth step, the calculation of ***Error of parameter*** is done by using formula:

$$S_{bi} = \sqrt{S_{ii}}$$

And at last, the t-value is calculated as:

$$t - val = \frac{|\gamma|}{S_{bi}}$$

Now, the statistical verification of individual parameters can be realized by comparison of the calculated t-value with table value, also called t-tab. If the t-value is greater than t-tab, the null hypothesis is being rejected and therefore it is proven that the particular parameter is significant, based on criteria:

$$t - val\ > t_{tab} => reject\ H_0$$

After the check of all parameter's significance level, it is necessary to evaluate fit of the whole model. For that, correlation coefficient and coefficient of determination is used.

The **C*orrelation coefficient R*** determines the tightness and dependence between variables. The result is in interval <-1; 1>. The closer to zero the correlation coefficient is, the lower is the tightness and dependence between variables. The formula for correlation coefficient is:

$$R = \sqrt{1 - \frac{S_u^2}{S_y^2}}$$

Where:

S_u^2…represents variance of residuals (sum of square differences between theoretical and real values divided by number of observations in the model, the formula is described above)

S_y^2…stands for the total variance (sum of square differences between average and real values divided by number of observations in the model) and is calculated as:

$$S_y^2 = \frac{\sum_{t=1}^{n}(y_t - \overline{y}_t)^2}{n - p}$$

Where:

$\overline{y}_t$…means average values

Coefficient of determination R² evaluates the compliance of model with data. Its value indicates the extent of changes in endogenous variable explained by changes in exogenous variables (the proportion or percentage explained by the regression model). The calculation is done according to following formula:

$$R^2 = 1 - \frac{S_u^2}{S_r^2}$$

Where:

S_r^2…is a variance of dependent variable

The result value of the coefficient is from the interval <0.1>. If the value equals zero, the function indicates that there is no relationship between the variables. However, if the value of the coefficient of determination equals to one, the theoretical value of the endogenous variable is equal to its true value. Therefore, changes in exogenous variables express changes in endogenous variables by 100% as the coefficient is expressed in percentage.

Adjusted coefficient of determination $\bar{R}^2$ is utilized when considering the extension of the number of variables in the model. With addition of another variable to the model, the coefficient of determination usually does not decrease, on the contrary it is most likely that it is going to increase. The formula is:

$$\bar{R}^2 = 1 - (1 - R^2)\ \frac{n-1}{n-p}$$

Where: **p**…number of estimated parameters in individual equation

<u>Econometric verification</u>

Testing for autocorrelation

For testing of autocorrelation of the first order the Durbin-Watson test is used by formula:

$$u_t = \rho * u_{t-1} + \varepsilon_t$$

$$DW = \frac{\sum_{t=2}^{n}(u_t - u_{t-1})^2}{\sum_{t=1}^{n} u_t^2}$$

Where: u_t…residuals

The values of test are in interval <0;4>

Where:

d = 4…there is negative correlation

d = 2…there is no autocorrelation

d = 0…there is positive correlation.

For higher order then the Breusch-Godfrey serial correlation LM test is used as Gujarati (2002) explains.

$$u_t = \rho_1 * u_{t-1} + \dots + \rho_k * u_{t-k} + \varepsilon_t$$

LM test can be evaluated according the comparison of calculated p-value with selected level of significance (alpha). The criterium is: if p-value is higher than alpha level, the null hypotheses assuming no autocorrelation cannot be rejected.

Testing for heteroscedasticity

For heteroscedasticity testing is the Breusch-Pagan test being used and as Green (2003) describes, is evaluated by calculated p-value. Test proves, whether the residuals have the same finite variance and thus, if they are homoscedastic.

Testing for normality

According to Gujarati (2002) to test normal distribution of residuals, the Jarque - Bera test is used and again evaluated by calculated p-value.

$$JB = \frac{n}{6}\left(s^2 + \frac{1}{4}K^2\right)$$

$$S = \frac{\hat{\mu}_3}{\hat{\sigma}_3} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{3/2}}$$

$$K = \frac{\hat{\mu}_4}{\hat{\sigma}_4} - 3 = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^2} - 3$$

Application of Econometric model

Elasticity

$$\boldsymbol{E} = \frac{\partial \boldsymbol{y}}{\partial \boldsymbol{x_i}}\,\frac{\boldsymbol{x_i}}{\hat{\boldsymbol{y}}}$$

(Čechura, 2017)

Ex-post Prognosis

$$\boldsymbol{Y'_T} = \boldsymbol{MX_T}$$

Where:

$\boldsymbol{Y'_T}$…is a matrix containing equilibrium vectors of individual endogenous variables based on the model as a whole

$\boldsymbol{X_T}$…matrices containing vectors of each predetermined variables included in the model.

M…Matrix of Multipliers

$$\boldsymbol{y_t} = \boldsymbol{MX_t} + \boldsymbol{v_t}$$

$$\boldsymbol{M} = -\boldsymbol{B^{-1}} * \boldsymbol{\Gamma}$$

Where:

B…matrix Beta, containing dependent variables from the model

Γ …matrix Gama, including the independent variables of the model

$\boldsymbol{\widehat{Y}_T}$…theoretical values representing the ex-post prognosis, resulting from the formula

(Hayashi, 2000)

Ex-ante Prognosis

$$\boldsymbol{\widehat{Y}_T = x_t' \, b}$$

$\boldsymbol{\widehat{Y}_T}$…conditional point forecast of average values of endogenous variable in time t

$\boldsymbol{x_t'}$…vector of predicted values of exogenous variable in time t

(Hušek, 2007)

3 Theoretical Part

3.1 Market and its functions

The basic economic issues of the market are what, how and for whom to produce. The market is generally being defined as an area where the formation of price and exchange realization takes place as a result of intersection and the interaction of supply and demand. However, to perceive the market as a tangible place located in a particular area is very misleading. It is rather preferable to perceive the market as an arrangement or a system in which the seller and the buyer interact with each other, thereby determining the price and selling quantity of a particular good. There are always sellers on the supply side and the buyers on the demand side playing roles during the exchange realization. These actors called market operators or entities and legally can be both physical and legal persons. (Samuelson, Nordhaus, 1995)

Two foundational subjects have a key role in pricing. These are the recipients of the price and the price creators. While the price creator participates in price setting, the price recipient does not dispose by this ability and can only accept the set price. If the recipient does so, the exchange will take place, otherwise the trade will not be realized. On the supply and demand side the key objective is the needs satisfaction and the utility maximization from the consumption. At the same time, it is evident that there is a totally contradictory way for both market players to maximize their utilities. While supply-side entities are trying to sell their goods at the highest possible price, entities on the demand-side have the completely opposite goal of buying goods at the lowest possible price. The effect of interaction of these completely antagonistic requirements creates a market price. This can be defined as a common consensus on the price level at which the exchange is realized. If the market price is the result of an intersection of the supply and demand function, there is a market equilibrium, i.e. a situation where the demanded quantity equals the offered quantity and there is neither a shortage nor a surplus of goods on the market. (Holman, 2005) Price plays a key role in the market mechanism. Factors of production, goods and services, everything that enters the market as a product, have its price on the market. The market price fulfils the functions of information, allocation, motivation and differentiation in the market mechanism. Using the information function, prices provide information on the current relationship between supply and demand on the markets, thus signalling producers to reduce or increase their production and consumers make the optimal choices accordingly. The allocation function directs the flow of factors of production to individual industries. Given the motivational function, the owners of production factors who react to price changes continuously are rewarded. (Jurečka et al., 2013)

However, the market equilibrium is not a standard situation in the economic environment. Much more common is the situation when one of the price-determining entities is more willing to exchange than the other one. In such a case, although the parties agreed on the market price, the benefits of both exchange actors were not equally maximized. There is a so-called overhang also called excess on the supply or demand side caused by this kind of situations. Furthermore, the economic theory claims that in the absence of market equilibrium, the purported market mechanism begins to work. It serves to balance both positions and thus, puts the market in balance. (Samuelson, Nordhaus, 1995)

Bellová (2011) distinguishes 4 essential elements for the market mechanism functioning. They are demand, supply, price and quantity. If there is an excess of supply on the market, the supplied quantity of the given good increases due to favourable exchange. The increase in supply, inevitably leads to a reduction in the consumer surplus, thereby reducing demand. This increases the amount of unsold goods to which the supply side entities respond by lowering of prices. As prices fall, demand increases again. This situation is constantly repeated and lasts until the market price is balanced with the equilibrium price and the market is in equilibrium. The situation is similar when there is an over-demand. With the lower price, the goods become exclusive. Demand-side entities pursue the offered goods, but the supply is low and therefore, the demand cannot be satisfied. By the effort to meet and fulfil the needs, the price increases as a result of competition on the demand side. There is neither a surplus nor a shortage existing at the equilibrium point on both the demand and supply side. Despite the function and operation of the market mechanism, the situation when the market is in balance is a very short-term phenomenon and is rather a rare phase. (Holman, 2005)

The operation of the price mechanism is strongly dependent on the form of the market structure. This may prevent the function of the market mechanism itself, but at the same time it may speed up or reversely slow down the process. Market structures are divided into markets of perfect and imperfect competition. Under the imperfect competition, there are furtherly distinguished three types of market structures. Monopoly, oligopoly and monopolistic competition. Individual market structures exist both on the supply and demand side and operate on the same principle. (Svoboda, Šrédl, 2012)

Monopoly competition

A monopoly is a market structure in where a single seller contains the entire market because it offers a product that has no close substitutes. (Frank, 1995)

The sole creator of the supply decides both the quantity of the given good and so its price. As Svoboda and Šrédl (2012) describe, this situation is caused by no competition on the supply side. Therefore, the demand side do not have the possibility to request the given good anywhere else but at the monopoly. A monopoly position arises from the existence of barriers that prevent new firms from entering the market. For the absence of competition reason, is the monopoly supply equivalent to the supply of the whole sector.

Companies are prevented from entering the market or are not interested in it for several reasons. First type of these barriers is when there is one company in the industry that is able to meet demand at lower average costs than its competitors. For example, the ownership of a unique patent for a new technology. Another type of barriers might be the ownership of a resource that is necessary for production by only one company. This case is an example of so-called *natural* monopoly.

One of the barriers may also be a high entry costs or the impossibility for another entity to operate within the segment. Thus, monopolistic markets are generally less flexible in their response to the amount of supply and market price and are also less economically efficient. (Svoboda, Šrédl, 2012)

Oligopolistic competition

Oligopoly Svoboda and Šrédl (2012) define as an imperfect competition type of the market model, characterized by a small number of companies in the industry and a relatively high degree of interdependence in their decisions on prices, quantity and product quality, etc.

There are only a limited number of companies existing within the industry that together are able to influence the price and production of a given good on the market. Unlike the monopoly, individual entities have to take into consideration not only the potential reactions of the demand side but also competing firms when changing prices and quantities. There is a strategic dependence working between the companies. Each supply-side actor is, to the certain extent of its limitations, able to cause the change in the whole sector.

According to Holman (2005) entities in an oligopolistic structure have the option of either cooperating on the basis of a cartel deal or competing with each other. Cooperation agreements may set the same price levels, quotas in production quantities or may territorially divide the market. If the entities subsequently implement the given agreement, they create a market situation reminiscent of a monopoly. In case of the non-compliance of the agreement, a price war may be unleashed among the entities, bringing the situation closer to perfect competition. Moreover, the actual formation of cartels is prohibited and therefore, the fulfilment of obligations in the contract cannot be enforced by a legal force. When firms behave like cartels there is a profit maximization happening based on imperfect competition, otherwise the situation is getting close to the perfect type of competition.

Perfect Competition

Perfect competition is a theoretical concept that never occurs in the real economy. Reality might only approach it.

Within the perfect competition, there exists a homogeneous product offered by different entities. Thus, product differentiation is not possible. At the same time, no entity controls the entire market and so, cannot determine the price of the good. This is determined only by competition competing and by demand. The producers are thus merely recipients of the price. There are also no barriers to entry or exit from the market of other operators in the context of perfect competition. Further to profit making, other companies are entering into the industry, which causes the economic profit over a long period in perfect competition to be equal to zero. At the same time, there is perfect information on the market. (Holman, 2005)

3.1.1 Supply and Demand

Supply

Generally, the supply can be defined as a function that represents the quantity of goods that producers are voluntarily able and willing to deliver to the market at a certain price. Supply is usually classified as market, individual and partial supply. The market supply consists of a summary of all the supplies of all the sellers. An individual supply consists of one manufacturer's supply whether a sub-supply is the supply of one product by several dealers. The size of the supply depends on several factors. These include output price, inputs price, competition, technology and more. The supply can be expressed using the supply function. That shows the dependence of the supplied quantity of the given good on its price. If the price of a given good rises, so does its quantity. (Blažek, 1996)

Demand

Demand can be defined as a function representing the amount of goods that the buyers are able and willing to buy at a certain price. As in the case of supply, we distinguish market, individual and partial demand. Market demand is the sum of all demands. Individual demand can be defined as the demand for goods offered by one vendor. The partial demand then shows the demand for one product by several buyers. Demand can be represented by a demand function showing the dependence of the demanded quantity of a good depending on its price. As the price of the good increases, the demanded quantity decreases. Demand estimation is an important point in the pricing process, as if the price of the product does not correspond to the market situation, the company may face a financial loss. (Blažek, 1996)

Food Demand

Štiková, Sekavová and Mrhálková (2004) explains that there are several the most important factors affecting both the demand and the consumption of food. Among these factors belongs incomes development, development of consumers' prices of food together with non-food products and services, followed by supply and products availability on the market as well as advertising, promotion and health education. Furthermore, the food consumption is also impacted by extent and degree of saturation of consumers self-supply needs and so is by the quality of product development. By effective demand it is understood the relation of the income development to the development of market prices of food, industrial goods and services. That has especially the major impact on the consumption.

However, there is an obvious tendency of decreasing influence of prices on the consumption of food in recent years. This fact is proven by direct price elasticity as direct price elasticity tends to diminish in absolute value to approach zero. The consumption of different kinds of meat according to Ingr (2004) depends on the three following factors: health mark of meat, quality of meat and the consumer price. Moreover, the food demand has been also affected by entrance of large international supermarket chains into the Czech market roughly since 1995 according to Štiková et al. (2009). Especially because it has involved the market prices determination and development. On the contrary, accession to the European Union of the Czech Republic had a minimal influence on overall trends in food consumption. This is caused due to insignificant changes in the economic and social situation of the Czech population.

3.2 Consumer behaviour

According to Macáková (2003), an analysis of consumer behaviour in the goods (products) and services market is the basis for deriving a demand. It is important to realize with what intention customer comes to the market when analysing consumer behaviour. The aim of the consumer is to buy goods or services to meet his or hers needs, while being limited and influenced by his or her income.

Households act as consumers and thus create a demand side on the product (good) and service market. By buying and consuming a certain good, satisfaction and pleasure are reached. That is called by a term utility in economics. Utility expresses a subjective sense of satisfaction from the consumed product or service. (Brčák, Sekerka, 2010)

The aim of the consumer is to maximize the utility. There are distinguished two theories of utility according to the approach of utility measurability in economic theory. Cardinal and Ordinal.

3.2.1 Cardinal Approach

The Cardinal theory of utility says that utility is directly measurable and hence the values of total and marginal utility are known. The total utility (TU) is growing with every additional item up to point A. This point is called the saturation point. On the contrary, the marginal utility (MU) decreases with each additionally consumed asset down to the point A', where the marginal utility equals to zero.

Using the utility, economists were able to derive the demand function and its properties. In demand theory, it is said that people maximize their utility, which means they choose the set of consumption goods they prefer the most. (Soukupová, Hořejší, 2010)

Consumers have to decide how to divide money and time. People generally choose the products and services that are the most valuable to them. More precisely, utility (satisfaction) expresses how consumers evaluate different goods and services. The utility is rather the scientific construction used by economists to understand how rationally consumers allocate their scarce resources into goods that brings them a certain level of satisfaction. (Samuelson, 1995)

Economist Alfred Marshal introduced an indirect method of measuring utility in economics, by measuring the benefit of money that the consumer would be willing to pay for the good. (Holman, 2002)

By total utility in economics is called a satisfaction of the consumer from the whole quantity of goods or services. The increment of satisfaction from each other, additional unit of good or service is called marginal utility. (Holman 2005)

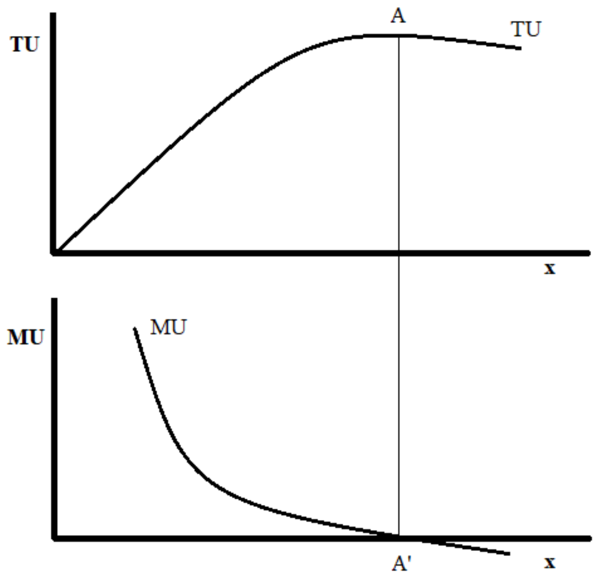
The law of diminishing marginal utility says that as the amount of goods consumed increases, the marginal benefit of that goods usually decreases. (Samuelson, 1995)

3.2.2 Ordinal Approach

Soukupová and Hořejší (2010) explains that in the second approach, the Ordinal theory of utility, it is not possible to measure the utility directly. The consumer is only able to determine which of the goods he or she prefers. Thus, the consumer is able to sort the combinations of goods according to their utility but is not able to determine the utility value of these combinations.

Furthermore, Macáková (2002) describes that it can be determined whether the total utility increases with the amount of consumed goods and thus, the marginal utility is positive, or whether the total utility decreases and therefore, the marginal utility is negative.

Picture 2: Behaviour of total and marginal utility in Cardinal approach



Source: Soukupová, Hořejší, 2010

The ordinalists reject any (directly or indirectly) measurability of satisfaction. They argue that the consumer is not able to give its satisfaction a dimension, but only an order. In the same time, the consumer can say whether the combination of A and B or C and D is more satisfactory for him or her but is not able to say how much more. In other words, it is possible to assign ordinal numbers to different combinations but can no longer assign dimensional (cardinal) numbers. (Holman, 2002)

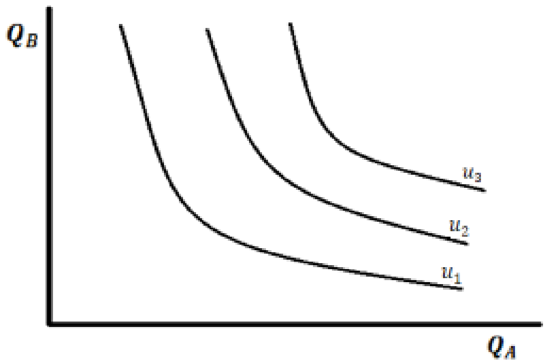
Indifference curves serve to illustrate combinations of two goods with the same benefit. (Soukupová, Hořejší, 2010)

The further is the indifference curve away from the origin, the higher the overall utility (u) the combinations lying on it represents. The graph above shows combinations of the amount of goods X and Y. Point X shows a greater overall benefit to consumers than point Y. (Brčák, Sekerka, 2010)

There are four properties of indifference curves according to Mankiw (1999):

a. Higher located indifference curves are preferred over the indifference curves below
b. Indifference curves are decreasing
c. Indifference curves do not intersect
d. Indifference curves are inverted (they are convex with respect to the origin)

Picture 3: Indifference curves in Ordinal approach



Source: Brčák, Sekerka, 2010

The set of indifference curves create an indifference map and shows there are infinitely many indifference curves in the plane that represent different levels of consumers utility. (Snyder and Nicholson, 2008c)

3.2.3 Substitutes and Complements

Holman (2005) explains that the level of utility and consequently the demand are influenced not only by the preferences of individual goods, but also by 2 other main factors. The first of those is a price. In fact, a rational consumer is not willing to pay a higher price for demanded good than its marginal utility. However, it is not only the price of the wanted good that matters, but also the price of its substitutes and complements.

As a complement it is understood a good that is consumed together with the primary good. In another words, if the price of complements decreases, the demand for the primary good increases and vice versa.

The substitute is a good that represents a possible adequate replacement for the primary good. Within the framework of substitutes, it is particularly important how unique the primary good is and how it differs from the competitive goods. Thus, it is clear from the definition of a substitute that its effect on the demand for a primary good is quite the opposite of the complement effect. If the price of substitutes decreases, the demand for the primary goods decreases as well and the other way around.

The second factor is the total income. The buyers' income increases as their purchasing power increases and therefore the demand increases. On the contrary, if the buyers' income decreases so does their purchasing power together with the demand. The so-called inferior or lower-quality goods are excluded from this fact. In their case applies, that with higher incomes the consumer will switch to another better or higher-quality substitute. (Frank, 1995)

3.2.4 Other Perspectives

Many other disciplines besides Economics deals with studying consumer behaviour as Psychology, Sociology or Marketing. Kubíčková and Šerhantová (2004) explains that understanding of the consumer behaviour variability is an important factor in achieving commercial success.

Consumer purchasing behaviour is influenced by *cultural, social, psychological* and *personal* factors. Every consumer is affected and limited by certain factors, for example the personal ones, such as age, gender, residence or income, their needs and wants, and definitely by their surroundings. (Koudelka, 2010) Every consumer has different wants and needs. The need is characterized by Vysekalová (2007) as a perceived lack of something and is usually a very various scale. Needs were defined and categorized by Abraham Maslow, who came up with a hierarchy of needs theory that is divided into five basic levels. There are basic physical and physiological needs, such as the need for oxygen, hunger and thirst, temperature regulation, sleep or movement at the lowest level of Maslow's pyramid. (Cejthamr, Dědina, 2010) According to Kodelka (2006) the purchasing decision-making process characterizes the process of consumer decision-making when purchasing a particular product and consists of five main phases. The first is to *recognize the problem*, or to realize the need, that can be solved by buying a specific consumer product. This is followed by *seeking information and evaluation of alternatives*. The next step is the purchasing decision and the final stage is a *post-purchase evaluation* of whether the consumer is satisfied with the purchase or not.

Related to purchasing decisions, there are *four main types of purchase* - extensive, impulsive, limited and customary. *Extensive* purchasing is typical when buying a more expensive product, where the buyer goes through a long and consistent decision-making process of searching for information and compares the products with each other. By *impulse* purchase is meant a purchase that was not planned in advance. A typical example is the purchase of an ice cream on a hot summer day. If the buyer undergoes a shortened decision-making process, that ends immediately after finding a product that meets buyers' requirements, it is a *limited* purchase. *Convenient* shopping is a routine and automatic matter of habit, such as everyday consumed goods like food, beverages or newspapers. (Boček, Jesenský, Krofiánová, 2009)

Routine purchase means custom shopping behaviour where the customer is loyal to the brand. There is no presence of a risk for the customers as they buy products they know or are familiar with and thus, have a great experience with. On the contrary, *impulsive* buying is characterized by frequent change of brands, the customer purchases here based on an immediate impulse, such as curiosity. (Bártová, Bárta, Koudelka, 2007)

Most consumers go shopping because of the need for some goods. They go unplanned without a shopping list. It is unlikely that customers would go to the store with the aim for a particular product brand, because they had seen a particular ad the day before the purchase and therefore wanted to buy the product. The shopping is rather unplanned, and the brand of the product is usually chosen on the spot, depending on the present offer. (Du Plessis, 2007)

As Yoon (2017) describes, the average customer sacrifices maximally a minute of his or her time by scanning the shelves in the shops, where the major difference can usually be observed only between price and packaging of the products. The customer is trying to choose the most beneficial offer and most of the time the decision when buying is made under the influence of emotions that have a big effect on the final decision nowadays.

3.3 Domestic Pig

In Latin known as *Sus Domesticus*, are classified as class of mammals belonging to even-toed ungulates order. They have a barrel-shaped body and a short tail. Typical is elongated muzzle ended with cartilaginous plate - snout. The construction of a foot that has an even number of toes is the main feature of even-toed ungulates. They have four toes on their feet - the middle ones are longer, the marginal ones are shorter, but still longer than, for example, for tours or deer. In summary, pigs are even-toed ungulates with a single-chamber stomach and are omnivores. (ZooPraha.cz)

The process of domestication started 8000 years ago, explains Široký (2012). The pig is of polyphyletic origin, meaning there were more domestication centres, and thus, there were more ancestors of domestic pig. For today's breeds there were three the most important ancestors, the European wild pig, Asian wild pig and Mediterranean wild pig. There were domesticated also other species of pigs from islands in southern Asia. There were noticeable differences in the way of farming around the world. In Asia pigs were kept directly in villages, in small pens and fed to high fat, while in the Mediterranean it was kept on large pastures, guarded by herdsmen, or in large enclosures with shelters. The spring to autumn system was applied to grazing and most animals were slaughtered in winter in Central and Northern Europe. And so, people bred a few dozen breeds until now. They differ mainly according to the purpose for which they are kept - whether for meat, lard or even for decoration as a pet.

There are many folk sayings and misconceptions about pigs. In fact, they are bright and clean animals, who are rolling in the mud only to get rid of their parasites and to cool down. Females are also careful and watchful mothers. (ZooPraha.cz) Pigs are very social creatures most often living in groups called sounders or herds, consisting of several families. The number of animals in a group depends on the livelihood conditions at certain territory. Hogs have a strict hierarchy in terms of social organization. The head of the sounder is always a sow. This position is determined by the age, body growth and authority of the animal. Boars leave the herd after reaching sexual maturity. Boars live as loners or in smaller groups and the presence of sows is searched only when trying to mate during the rutting season. Belonging to a certain group satisfies the herd instinct of the animal and helps physical contact with others to maintain body temperature in cold periods. Members of other sounders are tolerated by pigs in their area but do not allow them to integrate. Incorporation is only possible if the newly arrived fights in their place inside of the troop. Therefore, problems may often occur in holdings where the number of pigs in stalls has a high turnover. (Voříšková, 2001)

When communicating with each other, pigs use a complex system of murmurs and squeals. (Uhlenbroek, 2009) These sounds are used in different contexts and can express, for example, threats, warnings, temptations, or well-being and satisfaction. The decryption of the sounds during long-term monitoring of pig life is possible according to Hespeler (2007).

The best developed sense of the pigs is clearly the sense of smell, which is used primarily to obtain food, but also to protect against enemies. Another important sense is touch, especially the tactile organs at the end of the engraving near the olfactory holes. The disc-shaped end of the snout allows the pigs to engrave the ground while exploiting their well-developed sense of smell. These abilities of domestic pigs are used, for example, to search for truffles or detect unexploded mines. Hearing is also important to pig, but their ears are not as mobile as hoofed animals. One of the weakest senses is clearly sight. (Diller, 2002)

Naturally, one of the main enemies of pigs is a human who loves to hunt them very much. However, hunting is not only fun, but also a necessity. There might be a great deal of damage when pigs are overgrown. In areas where pigs naturally occur, their natural enemies are mainly wolves and bears. However, there are not enough of both beasts to be able to modify the number of pigs significantly by themselves. Piglets can then become prey to smaller predators, such as foxes. (Hespeler, 2007)

3.3.1 Breeds of Pigs

The typology of pigs deals with the shape characteristics in accordance with the requirements for achieving utility properties while maintaining the high health status of pigs. It assesses pig breeds by type, constitution and appearance. The objective is to select, through objective and subjective evaluation, those animals whose environment allows them to achieve the desired utility parameters. Especially for reproductive and mainly production indicators, that express the value and quantity of slaughter products that their offspring should achieve in fattening. (Stupka, 2013)

Due to the fact that people were doing hard physical work back in that time, there was a higher demand for fat, that was both a source of energy and a raw material for food preparation, initially it was mainly in England. And thanks to the easy storage and preservation, the lard types of pigs has spread and currently are kept mainly in Asia. In the 20th century, the growth of lean meat gradually began to be favoured over to the detriment of fat formation in selection.

Today, with the sedentary occupation of the majority of world population in the developed countries and the growing emphasis on healthy lifestyle, this tendency is even more pressing. Therefore, the pigs are bred for both a high level of fat (lard) and high conformation of meat (pork). Pig breeding therefore depends on national preferences and consumer tastes. It is possible to say that man grows tailored pigs. (Chovservis, 2003)

A breed is defined as a group of individuals of the same species that have the same most important physical and utility characteristics that they pass on to the offspring. Breeds can be divided into maternal and paternal lines. (Pulkrábek, 2005)

3.3.2 Feeding

Nutrition and appropriate feeding technique are highly related to achieving the highest quality of pork meat. Some of the factors influencing the quality of meat and fat are, for example nutrition level, choice of feed, composition and balance of feed rations, feeding intensity and frequency, health and hygiene parameters of feed, technology and technique of feed, application of growth stimulators or drugs. (Stupka, Šprysl, Čítek, 2013)

Currently, meat hybrids are used for fattening, i.e. crossbreeds of meat breeds. These genetically bred pigs cannot be fed with usual feeding, but nutrition with complete feed mixtures is required. The balance of protein to energy values ratio has particular importance in the feed ration. For pigs in fattening it is necessary to ensure the need for nitrogenous substances, i.e. proteins, as well as their biological value (optimal ratio of individual essential amino acids). (Steinhauser, et al., 2000)

Moreover, the influence of the trend of genetically modified plants, specifically GMO maize on slaughter value and quality of pig meat was examined. It was found it negatively affect the meat colour, drip loss and cooked meat loss. (Štefanka and Lagin, 2010)

The cost of feed represents over 50% of the total costs of farming, therefor it is necessary to pay sufficient attention to this economic aspect. At the level of nutrition and feeding, the weight gain of fattened pigs, the fertility of sows, market equilibrium, the ability of sows to raise a given number of piglets and the health of pigs of all categories are reflected. Feed must provide energy income and also necessary nutrients. (Foltýn a Zedníčková, 2010)

The structure of the average mixture for pigs (from piglets to pregnant sows) under the current breeding conditions has according to Zeman (2013) structure: Feed group (Feed) Share and is as follows. Cereals (wheat, barley, maize, oats) represents 80%, Protein feed (soya ex., Scrap, rapeseed ex., scrap, peas, bob) create 16%, Mineral (salt, limestone) are 3% and Premix of vitamins, amino acids and trace elements (vitamins, lysine, methionine, etc.) only 1%, resulting in total 100%.

3.3.3 Pig Farming

Hrala, Kašpar and Vitvarová (1996) describe a livestock production as an important part of agricultural production. Globally, the value of livestock production dominates over plant production. This predominance is created mainly by countries with developed market economies, i.e. developed countries where livestock production is the leading sector of agricultural production. Crop production in developed countries is focused on the requirements of animal production, especially grain production.

In most of developing countries, livestock production is a secondary sector for the lack of a quality feed base. The so-called protein hunger affecting the local population is the result of a shortage of food of animal origin. That has a negative impact on the physical condition of the population and thus, work performance as well. Therefore, the distribution of livestock production is influenced by two facts. Firstly, the fodder base and secondly, the consumption, or in another words, demand for products of animal origin.

The animal production is distinguished into two main categories, Intensive and Extensive type.

Intensive types of animal production:

1. *Alpine breeding model* is mainly developed in Europe, especially in the Alpine countries and in Scandinavia. Over the summer months the cattle pastures at higher altitudes whether during the winter, the cattle stays stabled.
2. *Intensive stable breeding* is characteristic for the majority of Central, Southern and South-eastern Europe. In this type of farming is the main income from agriculture crop production.
3. *Dominant stable breeding* is developed in areas of intensive livestock production, especially in Western and Northern Europe and so is in the North America. In this type of farming the main income originate from agriculture livestock production.

Extensive animal production models:

1. *Nomadic and Semi-nomadic breeding* is characteristic of dry regions of Central and Southwest Asia (Mongolia, Western China, Central Asia and Kazakhstan). The nomads accompany the herd along the routes according to the location of pastures with temporary settlements usually in proximity of water resources.
2. *Seasonal cattle movements between lowland and mountain pastures* are practiced in some Mediterranean regions of Europe and in the Andean countries.
3. *Modern extensive breeding* is developed for example on vast prairies of the North American Midwest or on the pampas of Latin America. Meanwhile in the dry semi-desert regions of Australia and on high-quality New Zealand pastures are by modern, extensive way bred mainly sheep. The pastures are being treated and sufficient water resources are supplied.

However, these differences are very relative, and in many countries the intensive and extensive style of livestock production is combined. (Hrala, Kašpar, Vitvarová, 1996)

3.3.4 Lifecycle of Pigs

The breeding of wild pigs takes place during the heat season, its beginning varies among different authors and it is variable due to natural conditions. Poruba (2003) consider October as a beginning with a peak in November and the possibility of extension until January. The summer heat is no exception. The pregnancy of the sows lasts for 114-118 days then, after which they farrow an average of five piglets. Piglets are born with open eyes and are able to follow their mother soon. Their fur is lightly striped, and that allows them a great cover in the shadows of the forest. Wild pigs may also be fertile in crossbreeding with domestic pigs.

The number of births per year is determined by the length of the intermediate period, which is optimally 152 days, i.e. it approximately 2.4 births per sow per year. Due to prolonged service period, this value is not achieved in practice. (Hájek, 1992) Moreover, Pulkrábek (2005) states that for sows, the most suitable period for mating is 210-240 days, with a body weight of 120-130 kg. Fertility in the first births is lower. Until 4.-5. birth fertility increases and decreases already after the 6th birth, when the number of stillborn piglets increases. Fertility of boars increases with the age and reaches the highest levels at the age of 18-30 months. (Žižlavský, 2002)

Wähner (2010) explains that postnatal mortality of piglets is influenced not only by care for born piglets, but also by balance and number of born piglets. As already mentioned, in the case of a large number of piglets per birth, their weight decreases and the piglets either do not survive or have a reduced growth ability. The ideal birth weight should be 1600-1700 grams. Postnatal mortality is also influenced by the maternal behaviour of the sows, i.e. how the sow behaves before, during and during suckling of piglets.

As mentioned in chapter *3.5.5. (Pork meat)* the OECD calculated that the average life expectancy of a pig is approximately 10-15 years. However, as the majority is bred for meat, it is heading for slaughter between the 4th-7th months of its life.

The transport and handling of animals prior to slaughter are very important factors affecting the final quality of the slaughter product. It is therefore necessary to avoid stress and its consequences by following a welfare principle when directing animals into the car, i.e. not using electric whips and poles. Suitable are full barriers, darker clothes and straight roads. (Stupka, Šprysl and Čítek, 2013)

Bečková and Daněk (2003) state that the optimum temperature in the car during transportation should be around 23 ° C. Due to a poor thermoregulatory ability of pigs it is necessary to ensure ventilation, watering and possible cooling of animals. Regarding the length of transportation, during longer transport the animals adapt to the conditions and regenerate. Therefore, transport should not be too short nor extremely long.

The recommended length of waiting time in the slaughterhouse is approximately 3 hours of rest, before the final phase of slaughtering.

The slaughter process significantly contributes to the final quality of pork. Regeneration of metabolism is no longer possible and therefore stunning must not affect the quality of the meat. The stunning and bleeding out technique is still under the discussion.

It has been proven that the electric stunning cause a decrease in pH and post-mortem stiffness. However, it depends on the time of the electric stream streaming. The shorter the stream, the less it affects pH and vice versa. High-voltage electric stream stunning is preferred. On the contrary, repeated application of electric pliers or imprecise placement of electrodes has a negative effect. (Bečková, Daněk, 2003)

Despite this, electrical stunning is the most widespread and used method. CO_2 stunning is an alternative method with many advantages, but very costly. This tries to imitate the state of anaesthesia. The gas concentration used for stunning pigs is around 40%. Higher concentrations cause rapid loss of consciousness and death within 1 minute. Although this method of stunning prevents many of the problems caused by electric shock (e.g., carcase damage, bleeding in the lungs and muscles, etc.), it is widely discussed because of contradictions in humanities medicine research.

Another alternative may be the so-called head-to-back method, which increases welfare at slaughter. It is done by applying electric forceps to the snout and continuing to the ears. (Stupka, Šprysl, Čítek, 2009)

3.3.5 Pork meat

Meat is defined as all of the body parts of animals, including fish and invertebrates in a fresh or modified state that fit into human nutrition (including blood, intestines and viscera). Meat is understood as skeletal muscle, either muscle tissue itself, or muscle tissue including fat, blood vessels, nerves, connective tissue, and other parts in a narrower definition. Meat is considered an irreplaceable part of human nutrition due to its content proteins, which are nutritionally the most valuable component, vitamins, unsaturated fatty acids and minerals (magnesium, calcium, iron, etc.). (Pipek a Jirotková, 2009)

Furthermore, meat is a rich source of nutrients and body benefits. It contains vitamins B, muscle growth proteins, zinc to improve immunity, it is also a natural antioxidant that helps with the production of red blood cells. (Agricdemy.com)

Another component group are lipids (fats), which indicate the sensory properties of meat. (Biomikro.vscht.cz)

Kameník (2014) describes that meat consumption plays a key role in the development of the human brain. However, certain types of meat contain increased levels of fat and raise cholesterol, thereby might be harming human health.

The physical structure of human genome is adapted for and dependent on diet containing meat and substances of meat source for about 4.5 million years. (Ingr, 2003)

Meat was originally obtained by hunting. Later, around 10 000 BC, humanity started with domestication of meat breeds. These animals also included pigs. The first mention of pork consumption dates back to medieval civilizations. Pork meat was consumed in medieval Egypt, Greece, Rome, but also in isolated China. Exactly from this the area comes an Asian pig, from which the origin of most breeds is derived. (Kameník, 2014)

People ate pork in the lower Egypt as early as the 3rd millennium BC, at the same time pig was considered to be one of the sacred animals in the upper Egypt. The Chinese were probably the first to taste roast pork. Pigs were the only domesticated animals kept for meat production according to deposits in China. (Doležal, 1993)

The spread and popularity of pigs throughout the whole world is closely related to their low environmental requirements and the ability to acclimatize. The pigs are resistant to both higher and lower temperatures and is not food intensive or demanding. Its stomach is formed to process almost any food and that is in any condition. Even the consumption of rotten meat or fruit does not cause any problems in pigs' digestion. Thus, the pig is capable to survive in most of the climate belts and has become part of the diet of almost all cultures. However, we also encounter such cultures that for some reason the consumption of pork meat refuses. This happens most often for religious reasons. (OECD)

The most known area forbidding the consumption of pork is the Middle East. Islam is the dominant religious movement, which considers pigs to be an unclean animal, and its consumption is prohibited within the Halal set of practices, in here. However, the ban on pork consumption is not limited to Muslim countries, as pork production in Israel is also strongly limited. The reason are religious specifics again.

Initially, it was a matter of social status to eat pork and meat in general. The main consumers of meat were usually men that were in the top positions of the social ladder in primitive civilizations. This status of the meat has lasted for centuries. The pigs were mostly bred in the countryside but consumed in the towns where the higher-status society with higher-income lived. (Kameník, 2014)

The same author describes, there was also a high cyclicality in meat consumption. Meat products were consumed mostly in autumn and winter seasons. However, this seasonality in meat consumption and production has been substantially suppressed over time due to political, socio-economic and technological changes.

Pork is the most consumed meat in the world and in the Czech Republic. The application of pork is divided into three directions. One of them is the processing industry, which produces meat products from this affordable raw material. Consumer demand for high sensory quality pork is another area application. The last area of application is the production of ham by dry preservation by slow natural processes. This is typical of Italy or Spain and requires the slaughter of pigs at high weights 150 - 180 kg (Pipek and Jirotková, 2009)

Pork is produced in livestock production. The basis for production are living animals whose potential is determined by the ability to reproduce and provide the benefit given to each species or breed of animal in livestock production. (Peterová, 2010)

Pork meat is obtained from pigs, ideally 7-10 months old. The meat is characterized by its pinkish colour, but some parts are darker red, some even with a greyish undertone. Unlike beef, pork is not easily digestible and is one of the fatter meats. (oahshb.cz)

The average life expectancy of a pig is approximately 10-15 years. The vast majority, however, is bred for meat and is thus heading for slaughter between the 4th-7th month of its life. Despite the relatively short life of meat breeds, it is possible to maintain number of pigs in the long term. Sows can give birth up to twice a year, and usually 6-12 piglets are born per birth. The gestation period for sows is usually only 4 months long, so one female can bring to life up to twenty piglets in a single year. The usage of a slaughtered pig is very wide. Around 75% of the total pig volume is processed into meat, but other parts such as lard and bristles are also used. (OECD)

Pig breeding and subsequent processing of pork meat has an irreplaceable position in the world and thus, also in the Czech Republic. As the most profitable seems to be the breeding of animals characterized by multiparity, short generation interval and frequency, which meets pig and poultry breeding.

In terms of utility performance, pigs are ranked as the most efficient livestock. This is mainly due to the high ability to synthesize proteins and fat reserves in the body, which is reflected in a considerable growth intensity. Pigs are also characterized by a high nutrient retention capacity for preservation and production needs, resulting in a very good nutrient conversion. Other positive characteristics of pigs include excellent fertility, milkiness, short gestation period, pregnancy and particularly favourable slaughter yield. (Stupka,Šprysl a Čítek, 2009A).

Meat quality can be determined as the sum of sensory (appearance, taste, smell, consistency) and nutritional values, together with technological (suitability of meat for processing, proportion of muscle and fat) and other properties (harmful substances, general health, welfare). Overall quality is the resulting set of conditions from breeding through feeding to slaughter and following technological processing. Pork meat is suitable for healthy eating by its composition, that corresponds to nutritional value. There is still a widespread perception in public that pork is too fat and therefore unhealthy. This claim is no longer justified today. There was a demand for breeding more animal just with a lot of fat after the war, because people worked hard manually. There was a lack of food and fat. Fat, which today is described as harmful, but it must not be forgotten that fat is clearly a source of taste and high energy, twice as high as pure proteins, it can be said. (VEPASPOL, 2018)

The quality of pork is influenced by several factors, that are divided into internal (genetic) and external (environmental) influences. One of the main influences is the influence of the animal's kind, where the colour of meat is a distinctive feature of species. The meat utility is related to the effect of the breed and the breeding process of animals. The differences in the production and storage of fat is mainly due to the effect of the sex of the animal. The quality of the carcass, the proportion of individual tissues and the composition and characteristics of the meat are primarily influenced by the age of the animal. An important factor is also health condition of animal, which affects the intake and usage of feed. Animals nutrition has a very substantial and at the same time complex intravital influence on meat quality. (Ingr, 2004)

The most valuable component of the meat is protein from both, the nutritional and processing point of view. Protein volume and values define the raw meat materials quality and also its suitability for further processing. Moreover, it is protein content that is the criterion for the quality and value of the finished processed meat products as well. Lean pork contains 75.1% of water, 22% of protein, 1.2% fat and 112 calories per 100 grams, compared to pork carcass where water share is 41.1%, proteins 11.2%, fat 47% and 472 calories per 100g. (Bender, 1992)

Feder's number represents the ratio of water to protein content in meat. It is an important criterion in assessing the composition of meat. Its value is relatively stable and is oscillate around the value 3.5. More specifically, for lean pork the value is 3.62. (Ingr, 2003)

The aim of production is breeding efficiency, rearing healthy well-developed piglets. Fattening and carcass value are included as an important characteristic of the production for meat production. Fattening is assessed by the average daily increments and feed consumption per kilogram of body weight gain. The proportion of meat and fat in the main fleshy parts of cold meat is referred to as a carcass value. Yield refers to the ratio of warm carcass (JUT in the Czech language) to slaughter weight. This value is on average 72-84%. The carcass value shall be assessed on the basis of the percentage of lean meat. (Pulkrábek, 2005)

Historically, it was common in the Czech Republic to buy pigs in live weight, where the decisive factor for classifying of quality class was the slaughter weight together with the subjective attitude of the buyer, who in the end of negotiation phase decided (determined) the amount of the paid price. There were often “fattening” deductions, followed by a significant reduction in the feed-in price and dissatisfaction of the seller - farmer. However, there could be the opposite situation when the seller closed a private agreement with the supplier and then the buyer was damaged. The exact weight was then determined 24 hours post-mortem or by calculation. These clearly unfavourable circumstances had to be changed.

Another factor in changing the meat buying system was the need to compare the quality of production within Europe. In order to compare increments, quality and overall objective statistics, it was necessary to introduce a uniform classification.

Moreover, the main and decisive reason for uniform classification was market demand. In order to determine the corresponding prices within Europe, it was necessary to have a product comparison tool - the SEUROP system. (Pulkrábek, 2001)

In general, pork is consumed even more than beef in the world (covering about 40% of the world's total meat consumption). Although, as with beef, there are groups of people who do not eat it for religion reasons. The dominant in meat consumption for the Czech Republic is a pork meat. It is a part of traditional Czech cuisine and its consumption in average is about 40 kg per year per capita. Unfortunately, a cheap pork meat from the import within the European Union is replacing domestic producers which is currently a problem. They are forced to sell meat even below the cost of production under these circumstances. (Svetobchodu.cz)

As for a pork production in the Czech Republic, it started to decline with slight fluctuations, after the revolution, and the downward trend continues to this day. The number of pigs in the Czech Republic has also been on a long-term downward trend since the revolution, being about three times lower than in the early 1990s. (CSO)

The development of the pork market in the Czech Republic is shaped both by local demand and by the situation on the world but mainly European market. Overall, especially for farmers in the Czech Republic, the situation is not very favorable in recent years. The Czech Republic was almost at the level of self-sufficiency in 2004, however in connection with the accession to the EU and liberalization of foreign trade, the sector showed low competitiveness, which was reflected in the passive balance of the trade. This fact is influenced not only by the import of pig meat but also by live pigs, especially piglets, which compensate for the domestic shortage of pigs for further processing. However, there is no shortage of pork in the internal market of the Czech Republic because of these imports. (Hojner, 2014)

Furthermore, the Ministry of Agriculture is trying to support Czech farmers and is looking for ways to support pig breeding. In addition to traditional subsidies to improve the economic situation of farmers and to maintain and improve the genetic potential of animals, it is also possible to use a support for the pig farming recovery. Moreover, there were programs for 2014-2020 period set, aimed at improving the welfare of sows, gilts and piglets, under the Rural Development Support (RDP). (Novák, 2015)

Czech Statistical Office monitors the food consumption in the Czech Republic. Using following statistical information, it is processed by balance method:

a. Livestock production
b. Definitive data on crop production
c. Industrial production
d. Initial and final inventory of agricultural enterprises
e. Initial and final stocks of food products producers
f. Import and export of food products from the statistics of foreign trade
g. Self-supply food products
h. Further data provided by the Ministry of Agriculture, Department of Agricultural Economics and Information, food-unions and other organizations

According to the mid-year population, the average the annual consumption per capita is than calculated. Consumption of meat is monitored in weight in kilograms of the carcass and consists of poultry, pork, beef, veal, sheep, goats, horses, game and rabbits according to the methodology of Czech Statistical Office. Out of these, the consumption of sheep, goat and horsemeat is monitored together in one group but not individually. Innards are included in consumption of individual kinds of meat and those records are monitored as additional information. (Czech Statistical Office, 2013)

3.3.6 SEUROP system

At the beginning of the 21st century, the SEUROP classification was introduced in all member states of the European Union, Switzerland and Norway, on the legislative requirement basis for the obligatory classification of livestock, especially pigs. This classification scheme establishes a coherent system and provides the price fixing based on pig conformation and the level of JUT conformation, both nationally and internationally. (Novák, 2015)

After accession of the Czech Republic to the EU in 2004, the customs of EU 15 contained in the EU Council Regulation 3513/93 had been taken over. The requirements for the unitary classification were implemented in the Czech legislation. The basis of the SEUROP system is to assess the quality of carcasses, where the proportion of muscle is decisive. Muscle (lean meat) means the red transverse striated muscle determined in the detailed dissection of the carcasses (JUT). (Ingr, 2004)

According to Medical dictionary (2018) by dissection, it is understood a separation of body parts or tissues according to their natural boundaries.

Output data (classification) are decisive for the price paid and consequently are a significant feedback for breeders, who by adjusting the feeding rations or other aspects of breeding can achieve better quality (higher conformation) of animals and subsequently achieve better (higher) feed-in price. The buyer is interested in buying high-quality meat that does not contain much fat and has a high proportion of muscle, as today's customer requires. The own classification is determined based on the determined weight and the measurement of indirect indicators (anatomical dimensions of the body).

SEUROP does not apply to carcasses (JUTs) weighing up to 59,9 kg for classification in group N and over 120 kg, which already belongs to the group T.

Description of categories: S - Superior (best yield, lot of high-quality muscles, least fat content) contains 60% of muscles, E - Excellent (high quality, thus excellent result) has 55-59.9% of muscles followed by U - Very good with share of muscles between 50-54.9%, R – good with 45-49.9% of muscles, O – fair (satisfactory) having muscles share from 40% to 44.9% and finally, class P - poor (low conformation, overall low weight) containing less than 40% of muscles. From some fast food producers is purposely required a meat classified this way (beef) for the unique taste this meat has. (Pulkrábek, 2005) Therefore, the aim of all producers is to achieve the best possible monetization, which corresponds to Classes S and E.

According to Pulkrábek (2005) housing, transport and animal welfare, as well as slaughter itself, can significantly change the quality of the final product. There is also a possible negative impact of pig breeding on high conformation, that is accompanied by an increased sensitivity of animals to stress. Incorrect breeding and bad handling of animals during transport and slaughter may result in variations of the meat quality, which significantly reduce its price. It may cause the consistency of PSE (pale, soft, exudative) meat that is light, soft and watery, or DFD (dark, firm, dry) that is dark, firm and dry (Gahm, 1995)

The obligation to classify pigs for slaughter applies to all slaughtering establishments under Commission Regulation (EC) No 1249/2008. In establishments where the average monthly slaughter is less than 200 pieces, and in establishments where pigs are only born and fattened in their own breeding facilities, the member states have the option not to apply the SEUROP scale. Act No. 110/1997 Coll. in the Czech Republic there is an obligation to ensure the classification of SEUROP in all enterprises that slaughter more than 200 pigs per week on average per year. (Novák, 2015)

Inspection takes place directly in the slaughterhouse by using a special gun. During the inspection, the quality of each carcase pieces is assessed objectively and then is classed into individual quality category according to the SEUROP system. An independent veterinarian carries out the classification. This contributes to a better relationship between seller and buyer. The controls carried out in this way lead to an increase in the quality together with the quantity of pigs for slaughter. (Stupka, Šprysl, Čítek, 2013)

Ministry of Agriculture, specifically the Food Market Surveillance Department, manages the carcase classification of animals for slaughter in the Czech Republic. It cooperates with other bodies and competent organizations, that are Institute of Animal Science (IAS), Czech-Moravian Breeders Association, Central Institute for Supervising and Testing in Agriculture and The State Agricultural Intervention Fund. Where Ministry of Agriculture elaborates proposals for modification of the Czech legislation in accordance with valid legislation of EU, unifies control procedures of official supervision at slaughterhouses and issues or withdraws certificates of professional competence of classifiers and inspectors. The training of classifiers and inspectors is provided by the Institute of Animal Science. They are also responsible for monitoring of trends in the given area and thus participates in the development of methods of classification of carcases for slaughter animals and moreover, ensures verification of the correctness of classification methods used in the Czech Republic. The Czech-Moravian Breeders' Society collects and further process data on the classification of carcasses of slaughter animals according to SEUROP system. Meanwhile the Central Institute for Supervising and Testing in Agriculture performs state supervision over the implementation of the JUT classification. Agricultural producer prices are monitored and further processed by the State Agricultural Intervention Fund. (Ministry of Agriculture, 2017)

3.4 Econometric Modelling

Econometrics is a discipline connecting three individual scientific fields. Those would be Mathematics, Economics and Statistics. There are several definitions explaining this discipline. One of first might be from P.A. Samuelson, T.C. Koopmans, and J.R.N. Stone (1954) describing econometrics as the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference. Gujarati (2002) stated that econometrics literally means "measuring of economics" as a measuring is an important part of econometrics.

American economist W.H. Green (2003) explains, Econometrics is by no means the same as an economic statistic. Nor it is identical with what we call general economic theory, although a considerable portion of this theory has a definitely quantitative character. Nor should econometrics be taken as synonomous with the application of mathematics to economics. Experience has shown that each of these three viewpoints, that of statistics, economic theory, and mathematics, is a necessary, but not by itself a sufficient, condition for a real understanding of the quantitative relations in modern economic life. It is the *unification* of all three that is powerful. And it is this unification that constitutes econometrics.

Furthermore, according to Green (2003) the goal of econometric analysis is to estimate all parameters in the model followed by hypotheses testing to find values and sigs of these parameters, prove the validity of economic theory and effect of defined policies. This definition had been extended by Wooldridge (2006), that econometrics is used to predict economic time series and moreover, to test economic theories in all applied fields of economics to give an information to government, as well as to private policy makers. Czech professor Tvrdoň (2015) agreed that application of econometrics is used in many fields of economics. He pointed out that it concerns macroeconomic problems, international trade, public finance, regional and developing economics. Econometrics can be also utilized at social sciences, sociology, history, sciences of law and others.

However, Kennedy (1998) stated, that econometrics is the study of the application of statistical methods to the analysis of economic phenomena. Literally, econometric means 'measurement (which is the meaning of the Greek word metrics) in Economics'. …, econometrics include all those statistical and mathematical techniques that are utilized in the analysis of economic data. The main target of using these statistical and mathematical tools in economic data is to attempt to prove or disprove certain economic propositions and models. (Asteriou and Hall, 2007)

Finally, Hušek (2007) concluded that econometric analysis spins off the combination of economic theories, mathematics and statistics with aim to measure, verify or test especially economic and eventually social phenomena. The objective of this discipline is to give an empiric perspective into economic theory. The subject matter contains a mathematical-statistical formulation of economic theory alias econometric modelling, economic theory based on modification of estimated and testing methods together with calculation techniques (econometric methods) and applied econometrics that is application of econometric models in economic theory. The history of econometric is dated back to 1930s and it is connected with formation of Econometric society as well as founding of Econometríca journal.

3.4.1 Construction of Econometric model

Construction of econometric model can be divided into seven steps according to Czech professor Čechura (2017). Based on the aim of research, it can be composed of one or more equations. These models we distinguish on simple model, recursive model (one-way relationship) and simultaneous model (mutual or two-way relationship). The seven steps are:

a. Economic theory
b. Foundation of Economic model
c. Creation of an Econometric model
d. Data set (collection, processing and analysis of entering data)
e. Parameter estimation of Econometric model
f. Verification of Econometric model
g. Application of Econometric model

3.4.2 Economic Theory and Model

The very first step for econometric model establishment is to study documents to determine proper economic theory that is important for its definition and derivation. It is a set of definitions and assumptions about the behaviour of economic subjects that offers an explanation of economic phenomena and also their processes. (Hayashi, 2000)

Drafting an economic model is one of the most important steps in econometric model creation. The assumptions are derived based on economic theory, that is simplified abstraction of relationships in the real world and should help us explain our examined phenomena. It implies, that it is not always possible nor effective to describe economic reality in its full complexity. There are more ways how to interpret economic model (words, figures or algebraically).

Algebraically is the most common form that enables characteristic of big amount of relations between variables and to distinguish these relations with symbols. (Gujarati, 2002)

However, Tvrdoň (2007) prefers that firstly, the model is being described by words, sequentially, if possible, is the model transformed into mathematical form. To formulate economic model, it is necessary to determine a subject of examination, that is represented as an explained variable in the model; to choose relevant variables, which are explaining variables in the model and to define a form of function.

Mathematical formulation of an economic model:

$$\boldsymbol{y_{it} = f(x_{1t}, \dots, x_{nt})}$$

Where:

y…explained/ endogenous/ dependent variable in current time period

$\mathbf{x_{1\text{-}n}}$… explaining/ exogenous/ independent variables in current time period

Basically, there is not possible to see relationships in economic model.

Essential for economic model deduction is good knowledge of given relationship and factors that determine it. Meaning, it must fulfil specification presumptions, where belongs inclusion of significant variables, exclusion of insignificant variables, choice of right function form, stability of parameters and assumption of non-existing simultaneous relationship between endogenous and exogenous variables or among exogenous variables. Defined economic model demonstrates confrontation of economic theory with reality. (Čechura, 2017)

As Hayashi (2000) further presents, the choice of the right function form requires a notation of a relationship between variables in a form of the right mathematical function. In case of incorrect selection of a function, it might lead to distortion of dependency estimation. The volume of the bias of dependency estimation hinges on the differentiation extent of chosen functional type from the correct type in given value range. The most frequently used is a linear function, because it is considered an appropriate approximation of real relationships within a given value range.

Furthermore, specification assumption on parameters stability, according to Hayashi (2000), expresses the requirement on time and structurally invariant parameters of a model.

Moreover, Gujarati (2002) stated that assumption of non-existing relationship between endogenous and exogenous variable, resp. variables means, that it is exactly known for what kind of relation there is an interest. With usage of economic theory, it is possible to divide variables on endogenous that are generated as part of model structure and exogenous, resp. predetermined variables, which values are being formed outside of model relationship.

3.4.3 Econometric model

The basic difference between economic and econometric model is that economic model becomes an econometric model by addition of stochastic variable to its economic form and by determining of functional form of the model. Stochastic variable represents partly a total influence of all endogenous variables that were not explicitly included among exogenous variables, partially mistakes in observations occurring in measurement of variables used and mistakes resulting from a simplification of relevant function form at the same time. (Tvrdoň, 2007) The stochastic variable incorporated in the model stands for random errors that arise by exclusion of some significant explanatory variable, for example, inaccurate specification of analytical or mathematical form of the model and so on. The notation for residuals in the model is letter "u". (Hušek, 2007)

It also includes parameters, that economic model does not. These parameters determine relationships inside of the model. We divide them onto structural and stochastics. Structural ones should be quantified. There is Beta, which is structural parameter of endogenous variables and Gama, which is structural parameter of exogenous variables.

Variables are distinguished as endogenous and exogenous. Endogenous variables are explained by the model. That is why those are called explained variables as well. Inside of the model, they are represented by letter "y". Exogenous variables on the other hand explain endogenous variables. Thus, they are also denoted as explanatory ones. These are marked by letter "x" in the model. (Čechura, 2017) Dependent variables that are a subject of model research are generated by the model and so are their values. Usually, they have a character of variables that are explained as a result of sum of explanatory and stochastic variables. Independent variables are always explanatory variables. Values and their changes of dependent variables are explained by them. The values of independent variables are determined by economic environment that is outside of the model. Due to that, it is not a subject of a given model research. (Gujarati, 2002)

3.4.4 Linear Regression Model (LRM)

Econometric model can be mathematically expressed in algebraic form as a Linear Regression Model (LRM) and has following structure according to Hušek (2007):

$$y = f(x_1, x_2, \dots, x_n) + u = \beta_{ji} y_{jt} = \gamma_{j1} x_{1t} + \gamma_{j2} x_{2t}, \dots, \gamma_{ji} x_{nt} + u_{it}$$

Where:

β…parameter of explained, endogenous variable (y), every time equals to 1 and therefore, we do not write it down into the model

$\mathbf{y_{it}}$…explained/ endogenous/ dependent variable (regresant) in current time period, its value is generated by a model. The part of a dependent variable, that is explained by a model is a theoretical value (ŷ) as an affect result of exogenous variables and random component. If there are *m* endogenous variables occurring in the model, it must contain *m* equations. There can be endogenous variables contained even among explaining variables in different equations of the model

γ…parameter of explaining exogenous variables (x), expresses what is the relationship between exogenous (predetermine) variables and endogenous variable

$\boldsymbol{x_{1t}}$…constant

$\boldsymbol{x_{it}}$… explaining/ exogenous/ independent variables (regressors) in current time period. They explain endogenous variable y and so, they should have a significant dependency on examined variable y, but not on each other. Their values are determined outside of a model

$\mathbf{u_{it}}$…stochastic variable/ error term/ residuals/ random component in current time period, also possible to express as ε_{it}, is a part of each equation of the model. Value of this variable cannot be gained by measurements, but as a part of model specification there are statistical hypotheses formulated on a characteristic and parameters of probability distribution of residuals. Its validity must be tested. (Hayashi, 2000) It might be, according to Tvrdoň (2007), partially caused by simplification, partly resulting from calculation errors or selection of inappropriate function type. It also contains the influence of all other variables on dependent variable, that are omitted form the model. A stochastic variable equals a difference between real (y) and theoretical (ŷ) value of endogenous variable in an individual equation

i-n…order of variables in particular equation

$\mathbf{j}$…order of equation in the model

$\mathbf{t}$…current period of time

However, apart of variables mentioned above, there can be several more types of variables distinguished in econometric model. Both exogenous and endogenous variables subdivide on variables in current time and lagged variables. This how, it is possible to dynamize the model by implying a lagged variable. Aggregate of exogenous lagged variables and variables from current period along with lagged endogenous variables is termed as predetermined variables. (Green, 2003)

$\boldsymbol{y_{it-z}}$…lagged endogenous variable, might explain other endogenous variables or itself in period t

$\boldsymbol{\beta_{ji}^{+}}$…parameter of lagged endogenous variable (y)

$\boldsymbol{x_{it-z}}$…lagged exogenous variable

t-z…express a delay of variable in the model as a result of an impact of variables in period of time t-z; where z = 1,...,t-z; and thus, dependence of variable at a level of economic magnitudes in previous periods on variable in current time t (Tvrdoň, 2007)

In the classical linear regression models the dependent variable´s rate of change remains constant whether for explanatory variables the slope curve is constant and the unit change. Gujarati (2003)

The multiple linear regression model is used to study the relationship between a dependent variable and one or more independent variables. (Green, 2003)

The model can be static, in case that it is model of one particular moment and there are only variables that are not changing in time included. Since majority of economical values are developing in time, there is a need for time factor to be embodied in the model. Thereby, model becomes dynamic. There are more possibilities how to dynamize a model. It can be done by adjunction of lagged variables, by expressing variables both in gradual differences or relatively, by inclusion of time vector (or trend) as extra variable or at last by adding one or more dummy variable into the model. (Hayashi, 2000)

Dummy variables are artificial variables that acquires only value of 0 if the phenomena do not occur and value of 1 in case phenomena occurs. They are used to express categorical variables, for modelling of structural shocks, changes of parameters or shifts in variables and moreover, for seasonal variables (dummy). (Čechura, 2017)

Linear regression model must fulfil several fundamental assumptions. In publication of professor Čechura (2017) are following:

b. Specification assumptions, mentioned above
c. Zero average of stochastic part u_t, E $(u_t) = 0$
d. Heteroscedasticity $[Var\ (u_t|x_t) = \sigma^2]$
e. Non autocorrelation of residua $Cov\ (u_i, u_j) = 0\ for\ i \neq j$
f. Independent variables are non-random and fixed in repetitive sets $Cov\ (x_{it}, u_t) = 0$
g. No multicollinearity
h. Normal distribution of residuals

According to Green (2003) are presumptions listed as:

a. Linearity – linear relationships between dependent and independent variables are specified by the model
b. Full rank – necessary assumption for parameters estimation
   –there is no significant relationship among any of the explanatory variables
a. Exogeneity of the independent variables – the expected value of the observation´s errors within the sample in not a function of the exogenous variables observed at any observation and hence, will carry no useful information to predict residuals (u)
b. Homoscedasticity and non-autocorrelation – assumption limiting the generality of the model
   – each residual is uncorrelated with every other one and has exactly the same, finite variance
a. Exogenously generated data – the data of independent variables could be a mixture of random variables and constants
b. Process, which generates errors (u) is independent on the process of generating data outside of presumption
c. Normal distribution – Residuals are normally distributed

3.4.5 Mathematical form of model and its equations

Mathematical form of econometric model can be divided according several criteria. As Hayashi (2000) describes in his publication, there is no exact manual on analytical form of examined dependencies in Economic theory, nor an information on correct number of equations in the model or their mutual relationships. It is possible to find out if the economic values are direct or indirect from the theory, that the individual subject acts rationally or maximizes its preferential function. However, it is not possible to get a manual on decision whether it is precise enough to describe the specific problem with one-equational model or whether it is necessary to formulate a system of independent or simultaneously dependent equations. Furthermore, it might be needed to use one of non-linear analytical form of dependency as the linear one offers only a gross approximation of reality.

Simulation models use the quantification of phenomena and their dependence as their means of expression. Quantitative simulation models are linear and nonlinear models, static and dynamic models, deterministic and stochastic models. In deterministic simulations we work with values of exogenous variables and its parameters. (Vančo, 2014)

Professor Tvrdoň (2007) distinguishes three model forms:

a. Simple models – these models contain a unit (identity) matrix I. There is only one explained endogenous variable in every individual equation of a simple model and thus, there are no relations between non-delayed endogenous variables
b. Recursive models – are also called recurrent models. These models has a triangle matrix contained. There is at least one non-zero element above the main diagonal occurs
c. Simultaneous models – there is conceded a possibility of reverse links (mutual or two-way relationships) between endogenous variables and also in here there is at least one non-zero element occurring above the diagonal in the matrix

According to Huška (2007) different three model forms exist:

a. Single equation model – is a stochastic model explaining one explained, endogenous variable depending on one or more explaining variables and error term
b. Multiple equations model – contains one or more explained variables and is composed of apparently independent equations where each equation it is possible to examine

separately as a single equation model. Residuals of these equations must be uncorrelated but relations between endogenous variables does not exist

c. Simultaneous model – is a composition of dependent equations system of stochastic simultaneous equations or non-stochastic equations. Simultaneous model is a model where not-delayed endogenous variables can have a function of both explained and explaining variables in the model and moreover, these are solution of all models equations in the same time

Dynamization of the model

If there were only variables that do not change over the time included in the model, it would be a static model that is a steady state at a given point in time. Since most of economic variables are changing and evolving with the time, it is necessary to include a time factor into the model, and thus make the model dynamic.

The model can be dynamized according to professor Čechura et al. (2017) in the following ways:

a. Including delayed variables
b. Expressing variables in successive differences or relative (1st differentiation)
c. Including the time vector as another variable (TV)
d. Including a dummy variable (artificial variables that take only the values 0 (if the phenomenon does not occur) and 1 (if the phenomenon occurs)

3.4.6 Data

Another important part next to the economic theory for good-quality econometric analysis is a necessary phase of collecting, aggreging, processing and analysing of entering data if these have required characteristic for models' parameters estimation. This phase determines a final form of econometric model and in that lies in its importance. The output of data collection is big number of figures that needs to be sorted and summarized. It is tabulation, various calculations of different statistical characteristics, graphical visualisation of data results and others. Before statistical processing of data begins, it is required to run a check of obtained data. It concerns adjudication if data correspond to the possible limits in what it might fluctuate. Furthermore, there might be found mistakes that might be done consciously, leading to bias retrieved data on purpose or of unconscious character, made by rewriting data or simple negligence. (Hošková, 2014)

To basic statistical characteristics belong:

- Characteristics of location (level) – median, mean, mode
- Characteristics of variability – variation, dispersion, standard deviation
- Characteristics of skewness – normal distribution – shape of Gauss curve
- Characteristics of point – positive or negative normal distribution (Hošková, 2014)

Two possible situations from data inspection might arise according to Čechura (2017).

The first situation is that the econometrist is not able to collect relevant and representative statistical data sample for proposed econometric model and subsequently it is not possible to quantify the econometric model and thus, the econometrist is enforced to return and pre-defined the model in a phase of economic theory so it corresponds with statistical data.

A data set must fulfil criteria of representativeness and homogeneous, therefor time series must capture characteristic of given population in time t=1,…,T credibly. (Čechura, 2017) If data does not comply statistical requirements, it is necessary to re-formulate equations and its variables or there are different methods to modify original variables. (Hayashi, 2000)

In the second situation, as Hayashi (2000) explains, the econometrist is able to collect a statistically representative data sample that allows him to further data processing and approach to the analysis. The main purpose of data processing phase is to rid of mistakes, aggregation or disaggregation and to transfer nominal expression to real expression.

There are several types of statistical data and those are cross-sectional data, panel data and time series.

a. Cross-sectional data - Cross-sectional data are variables related to individual entities in the same time frame. When summarizing information for different regions in a given period, they have a nature of spatial data. (Hušek, 2007)

b. Panel data - Within a statistical data, panel data are special type. These could be the financial income and expenditure of households, recognized for several periods sequentially. At the same sample of respondents, in different periods of a given program, they arise by repeating of a selected survey. Moreover, the analysis focuses on two main problems. Firstly, on gathering initial information on the relations nature between examined phenomena, and secondly, to respect all the assumptions of the econometric model. The second part concerns the statistical properties of a random component and time series. (Gujarati, 2002)

c. Time series - These are numerical values of variables in individual, successive periods, e.g. years, quarters or months. The number of observations affects the quality of the estimated model and therefore, it is necessary to pay attention to the number of observations in here. The length of the time series ensures the validity of the large numbers law and the central limit theorem, thus significantly affecting the statistical properties of the model. I.e. data are random enough. (Green, 2003)

3.4.7 Trend of Time Series

The trend reflects long-term changes in the average behaviour of the time series, respectively the general tendency of the development of examined phenomenon over a long period. It is a result of factors that has been operating in the same direction for a long time as e.g. production technology, demographic conditions or market conditions in the given area. The trend might have different character, it can be increasing, decreasing, steep, mild, it can change over the time, so it can be considered rather as a cycle. It can be smoother than the actual time series, or more variable. (Artl and Artlová, 2007)

These are usually non-periodic time series with random fluctuations in economic time series. A number of functions are used to balance these. The most commonly are used especially linear, power, semilogarithmic, exponential, quadratic, hyperbolic and logistic (so-called S-function) functions. Selecting the appropriate function type for expression of time series course is a necessary condition for the quality of the forecast based on the analysis of time series. (Tvrdoň, 2007)

According to Green (2003) time-series is understood as a sequence of spatially and factually comparable observations that are organized clearly by time in the direction from the past to the present. The aim of analysis of time-series is to elaborate models suitable for forecasting, interpreting and hypotheses testing concerning economic data. The starting point for time-series modelling is a one-dimensional model.

3.4.8 Multicollinearity

Correlation analysis deals with the degree of dependence among random data. The standard output of the correlation analysis is a coefficient describing the volume of dependence – the most often it is a correlation coefficient. Correlation coefficients serve as an extent of the expression of the "linear bind tightness". Correlation analysis describes linear relations between quantities. (Řezánková, Marek, Vrabec, 2000)

As Řezánková, Marek and Vrabec (2000) furtherly describe, the correlation coefficient R can range from –1 to +1. The square of the correlation coefficient R^2 is called the determination coefficient and takes values from 0 to +1.

To express the correlation between x and y, paired correlation coefficients are used in a simple Liner Regression. They are also used in multiple Linear Regressions to express the correlation between:

a. individual dependent variables x_i and independent variable y
b. between dependent variables mutually

Calculation of partial correlation coefficients are commonly part of standard statistical programs.

Multicollinearity is an undesirable phenomenon and expresses the dependence of one or more exogenous variables on other exogenous variables, explains Gujarati (2002). The perfect multicollinearity occurs when the multiple correlation coefficient is equal to 1. It is not possible to estimate the model, when there is a perfect multicollinearity present in such a model. There is always some degree of multicollinearity present in the model. High multicollinearity can be identified in the model by using a correlation matrix. The correlation matrix is a square matrix, ergo it is symmetrical along the main diagonal. It contains paired coefficients of individual explanatory variables.

The values that are greater than 0.8 respectively 0.9 indicate high correlation, known as multicollinearity, between variables. The correlation between the explanatory variables only is taken as relevant multicollinearity. Alternatively, a high value of the multiple determination coefficient R^2 for the model as a whole may be a symptom of multicollinearity. (Hušek, 2007)

Causes and impacts of multicollinearity:

a. The tendency of economic indicators' time series, in particular macro data such as gross domestic (national) product, consumption, investment, income, savings, export, import etc. to evolve in the same direction whereas showing the similar increments is the most common reason for the existence of strong multicollinearity of explanatory variables in the econometric model. Hušek (2007) explains that in the time series of post-war aggregate data for the Czechoslovak economy, the degree of multicollinearity is reinforced by the used planning methodology.
b. According to Green (2003), due to the non-experimental nature of the available data even in cross-sectional analysis the varying degree of linear dependence of sample observations of explanatory variables may occur. For example, if we estimate the consumption function, which includes disposable income and the amount of liquid assets (wealth) from the choice of observations for the selected group of households as explanatory variables, income and liquid activity are strongly, positively correlated since the differences in the changes of both independent variables are generally small. Similarly, we can expect collinearity between the explanatory factors like the number of employees and the value of the fixed capital when estimating the parameters of the static production function for individual firms from the cross-sectional data.
c. If there are differently delayed values of endogenous and exogenous variables, which are usually strongly correlated, included in the set of explanatory variables, significant multicollinearity is caused. (Green, 2003)
d. When using zero-unit artificial explanatory variables, the perfect multicollinearity can occur as Hušek (2007) describe. The complete linear dependence of the unit observation column of the special explanatory variable at the model's level constant and the columns of matrix X, containing only zeros and units is caused by a misspelled model specification, including artificial explanatory variables.

It is possible to reduce the Multicollinearity by, for example, usage of dummy variables, by appropriate transformation of underlying data, or by deletions of a variable, that causes the high multicollinearity. (Hayashi, 2000)

a. Ignoring a variable, as parameters are statistically significant
b. Omitting one of the correlated variables from the model
c. Transforming the underlying data into second - order deviations (gradual differences) or relative deviations

d. Replacing a given vector with a variable that causes multicollinearity with so called dummy variable, that is an artificial variable. (Tvrdoň, 2007)

3.4.9 Parameter Estimation

The signs (negative or positive) of individual parameters are determined based on the postulates of the relevant economic theory or we use information from other quantitative analyses and studies. It can be concluded that the sign of a parameter representing a particular marginal quantity can be only negative or vice versa, using a priori information. They are also explaining what kind of relationships between variables are. (Gujarati, 2002)

There are several methods to estimate the parameters of an econometric model. According to Gujarati (2002) the most common methods are the Ordinary least squares method (OLSM) and the Two-stage least squares method (TLSM). In this phase or step, static data are confronted with the economic model. Professor Čechura (2017) describes OLSM as a method very easily understandable, which is good characteristics for practical application. Furthermore, it is the most frequently used method for its simplicity of estimation and robustness in meeting the conditions. According to Hayashi (2000) the aim of Ordinary Least Square Method is to find parameters that minimizes sum of squares of theoretical values deviations (residual) of endogenous variables from their actual values. The estimated parameters by OLS must be the best, impartial and consistent, if the required assumptions and criteria are met. Only models that are linear in parameters can be estimated by OLSM. Models that are not linear in the parameters cannot be estimated by the LSM. In such a case, linearization of the model must be applied. Furthermore, the model type limits the applicability of the LSM as well specifies Hayashi (2000).

Two-stage least squares method (TLSM) is more used for estimation of parameters for simultaneous models. The parameter estimation is performed separately for each equation and is used for equations that are all precisely identified or over-identified. The principle of TLSM is the repeated application of the Ordinary least-squares method, first to estimate the theoretical values of the explanatory endogenous variables in a given equation and secondly to the actual estimation of the structural parameters of that equation. (Green, 2003)

3.4.10 Model verification

The estimated econometric model must be verified before its application for theoretical and practical economic problems, i.e. to verify and evaluate whether all obtained parameter estimates are primarily in line with a priori limitations of the initial economic hypotheses. The verification of the model includes, in addition to the decision on its feasibility, an assessment of the statistical significance of the estimated parameters and testing of compliance with predetermined hypotheses. (Hušek, 2007) We distinguish mathematical, economic, statistical and econometrical verification.

Mathematical verification

Mathematical model is according to Hayashi (2000) to verify, whether calculations are correct, and the left side of equation must be equal to the ride side.

Economic verification

Before using the model in practice, it must be firstly verified that it fulfils the initial economic assumptions and criteria on which it was built. The direction and intensity of the predetermined variables effect on the endogenous variable are assessed in the estimated model. The direction of dependence (direct and indirect proportionality) and the effect are determined by the positive or negative value of the coefficient of individual variable. The numeric value then determines its size. Therefore, the correctness of the mathematical signs is important. Based on these data, it is possible to verify the econometric model based on the initial economic theory. Economic testing of the estimated model is necessary for economic interpretation and usage of the resulting estimators. (Hušek, 2007)

Statistical verification

The model also needs to be verified in terms of statistical significance and conditions that are necessary to utilize specific econometric procedures. Statistical significance assesses as statistical significance of estimated parameters, individual equations, and also significance of the whole model. As is explained by Gujarati (2003) the statistical testing is composed of following steps:

Test of parameter significance

Probability value or p-value is defined as the lowest significance level at which the null hypothesis, that says that parameter is not statistically significant, can be rejected. If this p-value is smaller than chosen level of significance, the null hypothesis can be rejected. That means that the parameter is statistically significant. For parameters significance test the students t-test is used. T-test is applied for every parameter individually as Hayashi explains (2000)

Measures of goodness of fit

After the check of all parameter’s significance level, it is necessary to evaluate fit of the whole model. For that, coefficient of determination is used. Hayashi (2000) describes, the *correlation coefficient R* determines the tightness and dependence between variables. The result is in interval <-1; 1>. The closer to zero the correlation coefficient is, the lower is the tightness and dependence between variables. Theil (1978) explains that the adjusted coefficient usually reaches lower value than the classical coefficient of determination. As the degrees of freedom increase, the difference between these two indicators decreases. The number of degrees of freedom is obtained by subtracting the number of estimated parameters in equation (p) from the number of observations (n). Unlike the classical determination coefficient, the adjusted determination coefficient can also have negative values. If the adjusted coefficient has a negative value, this indicator is used as if it had zero value. The classical coefficient tends to generate too optimistic regression results, especially when the amount of explanatory variables is not too small in relation to the amount of observation, so in practice it is preferable to apply an adjusted coefficient of determination instead of the classical coefficient of determination.

<u>Econometric verification</u>

According to Gujarati (2002) the essence of econometric verification is to verify assumptions of econometric model, criteria necessary for application of particular econometric methods, tests and techniques. To verify the model, test of autocorrelation of residuals, test of homoskedasticity and test of normality of residuals distribution must be done.

3.4.11 Model Application

The result of verifications is according to Gujarati (2002) the decision whether to apply the model or reject it. If the model is rejected based of verifications results, it is necessary to start from the beginning. If the model is acceptable for further utility, it can be applied for simulation of scenarios, structural analyses or forecasts (prognosis).

Prognosis or prediction is one of the main goals of econometric modelling to Green (2003). It is an estimate of the values of the explained endogenous variables outside the observation interval, or a quantitative estimate of the probability of the future value of a particular economic variable using past and present a priori and premium information.

Green (2003) furtherly distinguish a several forecasts or predictions. The prognosis may be by extrapolation of future values or retroplation of past values. Moreover, there is the point and interval prediction. Meanwhile the point prediction is to estimate one future value for a given period, the interval prediction is an estimate of the confidence interval that contains the actual value with a certain probability.

Ex-post and ex-ante forecasts are distinguished for practical and methodological reasons. An ex-post forecast is obtained when both endogenous and explanatory predetermined variables can be determined with confidence for the certain period says Gujarati (2002). I.e. the prediction error is determined by comparing the *ex-post* forecast with the actual value of the endogenous variable. By this the suitability of the econometric model for forecasting can be verified. The *ex-ante* forecast is when the value of the endogenous explained variable, and some or all of the predetermined variables, are not known with certainty in the forecasting period. Therefore, these values need to be estimated or determined based on a priori information.

However, according to Vančo (2014) the simulation models use the quantification of phenomena and their dependence as a basis for the expression. Quantitative simulation models are linear or nonlinear, static or dynamic models, deterministic and stochastic models. The deterministic simulations work with the values of exogenous variables and its parameters.

When applying the model, the coefficients of elasticity are most often used in practice. Elasticity is the relative (percentage) expression of the effect of the explanatory variable on the explained variable.

4 Practical part

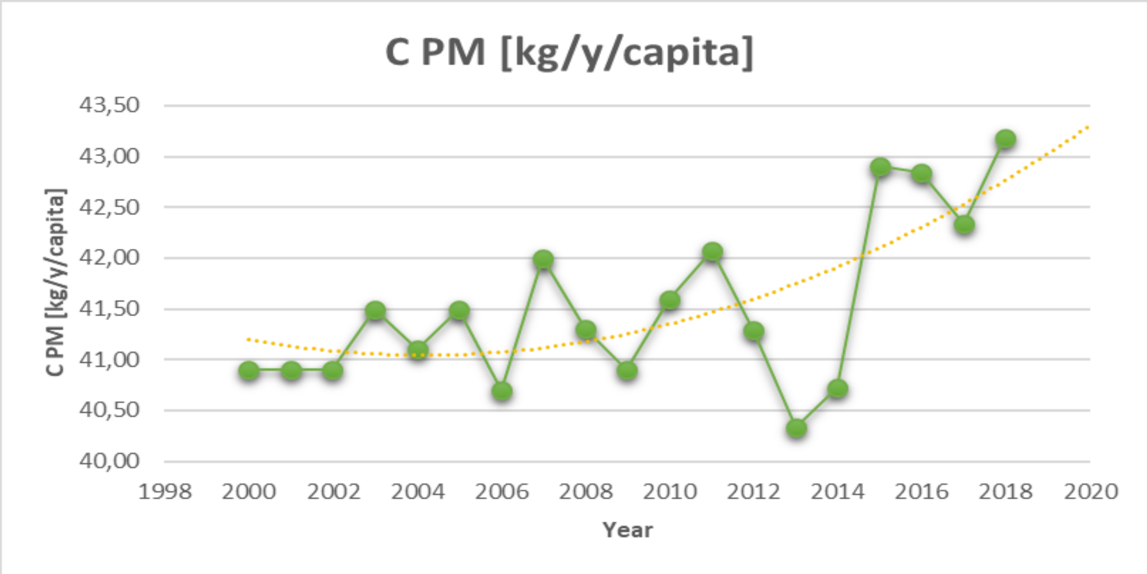
4.1 Development of Time Series

Development of Pork meat Consumption

The pork meat consumption has increasing trend during the observed period of time that consists of eighteen years. The average value of consumption of pork of this time series is 41.52 kg with the average grow rate 1.003. It ranged from 40.90 kg in 2000 to the highest peak where consumption of pork meat reaches 43.18 kg in year 2018. That is 1.055 growth rate since the base period. Since the beginning of the time series, the annual consumption remained 40.90 kg for three following years. From that point gradually rise by 1.44% and oscillate between 40.7 kg to 42.7 kg till the 2012 followed by steep decrease to the lowest point of the time series. The lowest amount of pork meat 40.33kg has been consumed in the year 2013. The consumption decreased by 2.38% that represents 0.96 kg per capita annually. After this drop, there was a biggest annual growth in consumption of 5.08% in 2015, which is of 2.18 kg per capita.

Trend function has been appointed using Microsoft Excel and most suitable trend function was selected according to the value of the coefficient of determination and by assessment of the graphical illustration. Used observations are from period from year 2000 to 2018 (T = 18). The trend function of the pork consumption is described by 45% with the coefficient of determination ($R^2 = 0.45$) and the polynomial function of the 2nd grade: $\boldsymbol{y = 0.009t^2 - 0.932t + 41.285 + u_t}$ that was selected. Point forecasts were than done by extrapolation of time series and therefore, according to chosen trend function, the forecast has been done for following two periods. Therefore, the forecast of pork meat consumption for year 2019 is 43.02 kg and 2020 is even 43.30 kg. Thus, based on these numbers, the trend should keep its increasing tendency visible in *Figure 1* below.

Figure 1: Annual consumption of pork per capita in kilograms (2000-2018)



Source: The Czech Statistical Office, Own elaboration

The most consumed kind of meat during the observed period from 2000 to 2018 in the Czech Republic is pork. The long-term trend and also share of the pork in overall meat consumption is increasing. It represented 46% of overall meat consumption in the year 2000 and its share grew to 47% in the year 2018. The second most popular kind of meat in the year 2000 was poultry with the share of 25% in overall meat consumption which share reached 31% in the year 2018. On the contrary, share of beef represented in the year 2000 just 14% of overall meat consumption and it even increased in 2018 when its share was accounting for only 9%. Still, it is the third most favourite kind of meat to be consumed.

The significant fluctuations in consumption might be caused by illnesses affecting pigs population. The deterioration of animal health adversely affects feed intake and usage, reduces increments and can lead even to animal deaths or necessary slaughter. Therefore, it is necessary to comply with anti-infection measures and to increase the resistance of pigs in order to prevent the emergence of diseases and the possible penetration of disease-causing organisms into breeding. (Ingr, 2003) A high concentration of animals in one place is also an ideal environment for the emergence and spread of various diseases and infections. Therefore, animals are often routinely fed with antibiotics to reduce the possibility of arising and developing epidemics. Webster (2009) considers the routine usage of antibiotics as an important factor in maintaining the current practice of pig breeding in large-scale farming. However, the expected European Union legislation is about to introduce a total ban on the use of antibiotics as zootechnical supplements or growth stimulators. The main reason is the fear of a possible risk to the health of animals and especially the consumers.

The diseases of pigs can be of different types. These are categorized depending on the origin of the disease. These could be a viral, bacterial or endoparasite or ectoparasite caused diseases. Known virus diseases of pigs are, for example, Swine flu, Porcine reproductive and respiratory syndrome (PRRS), Foot-and-mouth disease (FMD), Pseudorabies (Aujesky's disease) or Classical swine fever (CSF). These diseases can be described as acute and their reporting is mandatory. There are currently no difficulties with these diseases in the Czech Republic. (Bernardy a Drábek, 2008)

The problems with pig farming are also diseases that can break out between pigs and afterward some of them may also be complications for humans as Andrejev (1951) explains. An outbreak of a disease that is transmissible to humans, as has happened in the case of Swine flu, is another factor that can affect consumer trust in pork meat. For example, the pig may be a host of trichinella, also known as pig worm. This parasite causes the parasitic disease of trichinosis that is potentially a threat to humans. This is often one of the explanations and reasons why Muslims and Jews reject pork. However, the outbreak of the disease is prevented by sufficient heat treatment of the meat.

Swine flu

If we look into the decrease of consumption in 2009, in terms of disease, pigs were often mentioned mainly in connection with swine flu, that appeared in Mexico. Classical influenza, also known as Swine fever (CSF), Hog cholera or even Pig plague, is a highly contact regarding pigs, viral disease of animals' respiratory tract. It is characterized by a rapid course and rapid spread (Andrejev: 1951). However, the mortality of pigs is very low, about 1 - 4% and pigs usually recover within 7 - 10 days. It gradually spread all over the world and threatened with a pandemic outbreak by its characteristic. However, as WHO statement (2010) explains, this form was more severe due to the fact that it was caused by A (H1N1) virus, which origin was a mixture of swine, human and avian (or bird) influenza viruses. The mentioned disease was then transmitted through the air and attacked the human respiratory tract. Therefore, the infection could occur both by contact with pigs and so by contact with a sick person. Thus, there has been the whole world panic from the possible outbreak of a swine flu pandemic.

In August 2010, the World Health Organization announced the end of the swine flu pandemic, which to date has claimed around 14,000 laboratory confirmed victims. However, the swine flu, which first appeared in Mexico in the spring of 2009, did not significantly reduce the consumption of pork in the world. Similarly, mad cow disease and foot-and-mouth disease has shaken consumers' confidence in the safety of beef and sheep meat and has contributed significantly to reducing its consumption. Their place was filled and substituted mainly with consumption of pork and chicken.

According to Trousilová (2010), virus A (H1N1) did not occur among humans for the first time. This disease was also reported in 1976 in the US. However, it was managed to prevent a wider spread and, at the same time, research of prevention and vaccine for this disease began at that time. The problem, however, is the very good mutation ability of the A virus, which results in swine flu existence of several types. The similarity of virus A to the virus that caused the Spanish flu in the early 20th century, with estimation of 50 million victims also raised the concern. The virus A (H1N1) that caused the current infection belonged to the same group to which originated the originator of the Spanish flu. Therefore, the world responded with a number of preventive measures to mitigate the possibility of infection. The Egyptian government in particular had very fierce attitude regarding the preventive actions. In case when only one case of swine flu in its territory was registered, the slaying of all pig farms in the country had been ordered despite the repulsion of the World Health Organization, who described this method as totally unjustified. (Kryzánek, 2009) Afterwards, pictures depicting the very brutal treatment of pigs during the destruction of farms went viral all around the world. Under the excuse of preventing swine flu, the government was rather trying to improve the sanitary conditions of their state, while it was rather not successful much. Pig breeding in Egypt, that is primarily an Islamic country, was run by Christian minorities. Therefore, this act was often interpreted as an attack against a different religion group and also against the despised pigs by Muslims. Nevertheless, Christians in Egypt mostly worked as Zabbaleen, meaning literally garbage people in Egyptian Arabic. Those are people who were involved in the collection and sorting of waste, where the pigs were a significant help to them. For example, waste in Cairo, the capital of Egypt, accounts for up to 60% of food leftovers consumed mostly by the pigs that cleaned the streets this way. Therefore, after their removal, there occurred a sudden problem in the form of non-disposed waste, that other animals wandering the streets and companies hired by government are failing to cope with. This is an evidence that pigs are important and beneficial even to a state that to some extent despises them.

Classical swine fever

Historically, the signs of this highly contagious viral disease are high fever, rapid spread at the area of infection and subsequent mortality of the whole herd. The last time that classical swine fever occurred in the Czech Republic was in 1999 in the Znojmo district. Any danger at the current time is not reported. The costs of preventive controls of the State Veterinary Administration (SVA) for the period from 1992 to 1999 are approximately up to CZK 30 million. By comparison, the value of the herds disposed of in six epicentres of last occurrence in the year 1994 was quantified as CZK 172 million. Vaccination against this disease is prohibited within the EU. Thus, the only prevention of the state is the protection against the introduction of the disease. (SVA, 2017)

African swine fever

African swine fever broke out in 2008 in Azerbaijan, and followingly it gradually spread westward from there. We can observe the continuous decrease from this year in the consumption of pork. In 2014, it was registered in the Baltic countries and Poland, despite the implemented policies, there is no eradication of this disease reached. We can also observe a significant drop in consumption of pork in this year. Since 2017, data from Ukraine where the situation is critical are available. The African swine fever occurs throughout the whole territory. The last positive finding of this disease was a wild boar found only 60 km from the Slovak border. The reports confirm that the African plague also reached the Czech Republic at the end of June 2017. It penetrated the country from a wild pig that ran across the border to the city of Zlín. The State Veterinary Administration confirmed 97 wild boars dead as a consequence of African swine fever until the September 1, 2017. The African swine fever has so far only appeared in wild pigs and has not infected domestic breeding yet in the Czech Republic. The examination is carried out at the State Veterinary Institutes to detect the virus. Following confirmation is executed by the National Reference Laboratory at the SVA in Jihlava. (SVA, 2017) In year 2017 we can also observe the low of the curve.

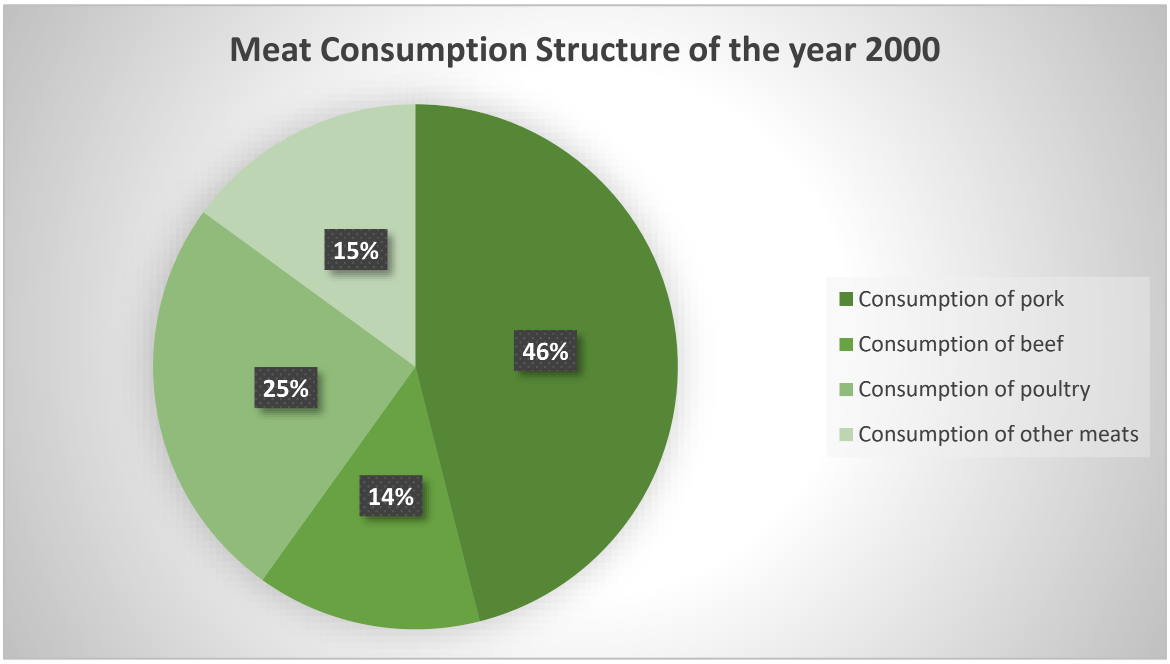
African swine fever (ASF) is an acute, highly contagious disease of pigs similar to the Classical swine fever. ASF is characterized by high, almost 100% lethality. Domestic and wild pigs of all ages can become infected with this infection. The original reservoir was a warthog of African origin from who ticks were infected. The virus is present in blood, tissue fluids, internal organs, secretions and also in excretions of diseased animals. It is highly resistant to both low temperatures and drying. The virus may be excluded by secretions and excretions as early as 1 or 2 days before clinical symptoms are observed.

The symptoms of disease are accompanied by high fever of up to 42 ° C, that might take even several days, depending on the development. The first symptoms appear when the temperature drops. The animals are sluggish, breathe heavily, do not accept food, suffer from bloody diarrhoea and vomit. Clinical symptoms are similar to classical swine fever (CSF), but the development is faster.

Similarly to Classical swine fever (CSF), the vaccination is banned in the EU and furthermore, there is currently no vaccine against the disease in the world even existing.

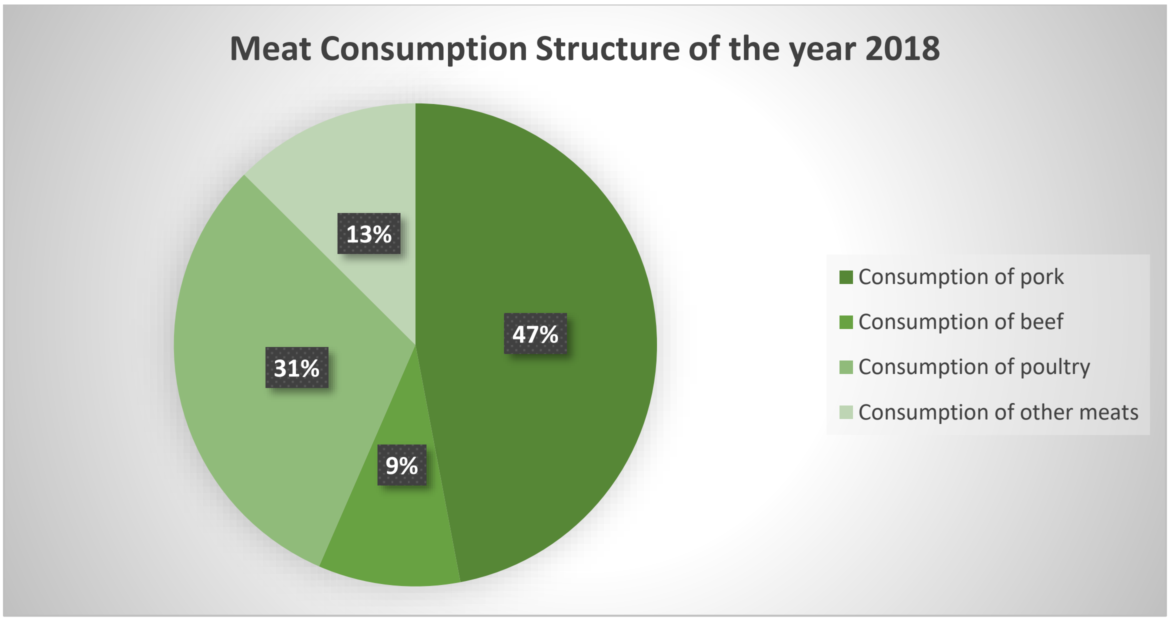
The share of other kinds of meat has slightly dropped from 15% in 2000 to 13% in 2018. Shares of individual kinds of meat in overall meat consumption are displayed in the *Figures 2* and *3*.

Figure 2: Structure of overall meat consumption in the year 2000 in the Czech Republic



Source: The Czech Statistical Office, Own elaboration

Figure 3: Structure of total meat consumption in the year 2018 in the Czech Republic



Source: The Czech Statistical Office, Own elaboration

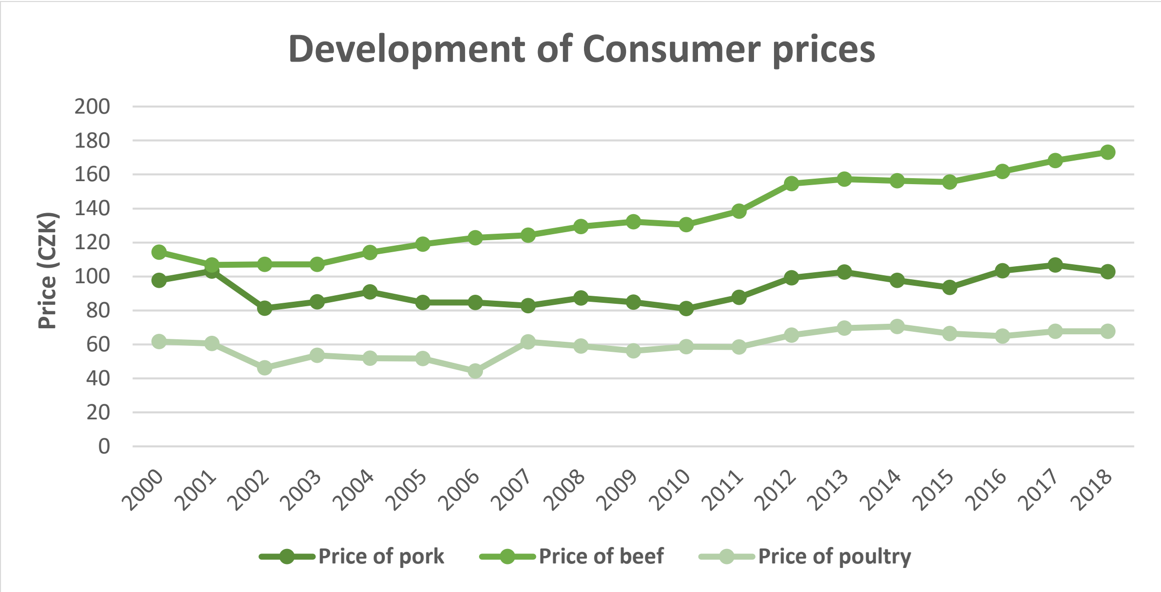
Development of Pork meat Consumer price

The consumer prices of poultry are the lowest compared to pork and beef and during the observed period are ranging between CZK 60.7 to 67.7 per kg. The steepest decline occurred in 2002 by the whole CZK 14.3 but the minimum was hit in 2006 with CZK 44.3 per kilogram. However, in the year 2007 there was the steepest inter annual increase of consumer prices of poultry by full CZK 17 and since this point, the prices are stable. The peak of chicken meat consumption time series was reached in year 2014 and it represents CZK 70.5. As a trend function for poultry consumer price was chosen polynomial function of 2nd grade: $\boldsymbol{y = 0.0706x^2 - 0.4612x + 55.216}$ that is explained by 55.14% as the R^2 is equal to 0.5514.

From the beginning of the observed period 2000 to 2018 the differences in prices of pork and beef were noticeable with exception of year 2001 when the consumer prices of these two commodities were nearly identical with the price CZK 103 per kg for pork meat and CZK 106.8 per kg for beef. Otherwise, the beef is more expensive for the rest of the time series and the trend is growing, whereas the consumer price of pork is more or less oscillating around its average price CZK 92.5 per kg. It was also a peak for consumer prices of pork in observed period in the year 2001 with mentioned CZK 103 per kg. The steepest decreases in price of pork by 26.9% followed after the year 2001. The drop was for CZK 21.9 per kg. In comparison to the prices of beef continued to increase steadily with the average annual rate of growth 1.2%. Beef reached its peak in the year 2018 on the level CZK 173.1 per kg which reflexes the increase by 51.6% from the base year 2000. The prices of pork after the steep inter annual decrease in

2002 tend to slowly rise with smaller falls and growths in the next years and therefore, are plus minus stable. The best suitable trend function for consumer price of pork was a polynomial function of 2nd grade: $\boldsymbol{y = 0.020t^2 - 3.14t + 98.49 + u_t}$ with $R^2 = 0.6141$, meaning the explanation of 61.41%. Whether the consumer price of beef is explained by 96.07% with polynomial function of 2nd grade: $\boldsymbol{y = 0.0968x^2 + 1.8946x + 103.87}$. Development of consumer prices of three most consumed kinds of meat in period 2000 to 2018 in the territory of the Czech Republic is displayed in *Figure 4*.

Figure 4: Development of consumer prices of pork, beef and poultry in the Czech Republic (2000-2018)

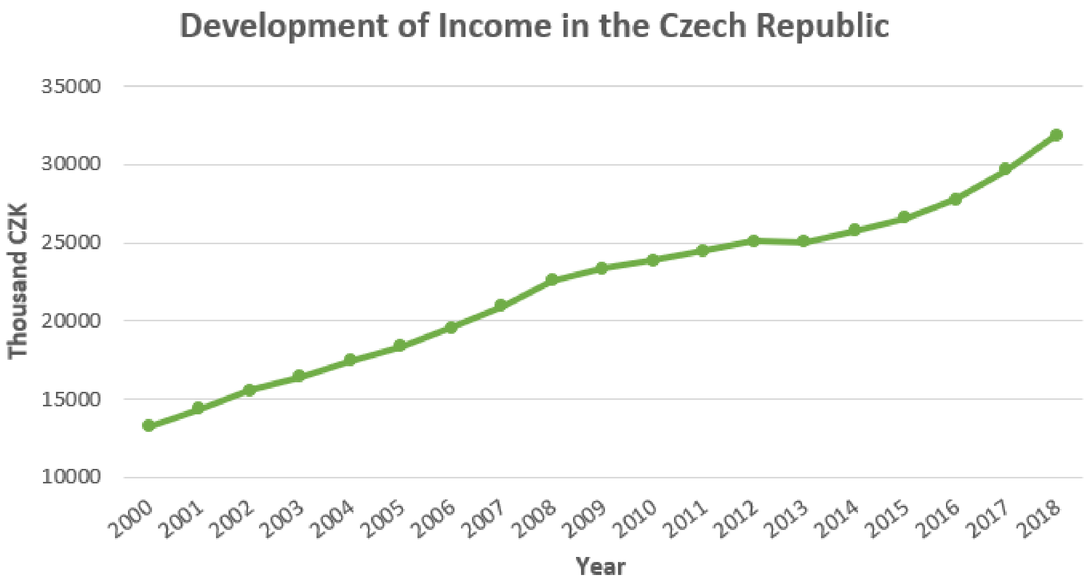


Source: The Czech Statistical Office, Own elaboration

<u>Development of Income</u>

Regarding to development of income in the Czech Republic, the steadily growing tendency is observable within the set timeframe of years 2000 and 2018. The very minimum is at the beginning, at 2000 with average monthly income of CZK 13 219 thousand per capita, whether the peak is reached in year 2018 with average monthly income of CZK 31 868 thousand per capita. That is an increase by 141% from the base year of 2000 with average growth rate of 1.68. The only drop compared to previous year in the whole time series happened in 2013 when the average monthly income of CZK 25 067 thousand slightly decreased to CZK 25 035 thousand per capita and that reflex decline by 0.13%. From that point the average monthly income in the Czech Republic continues to grow. Income is the best explained by 98.05% ($R^2 = 0.9805$) by 2nd grade polynomial function: $\boldsymbol{y = -8.2579x^2 + 1094.4x + 12332}$

Figure 5: Development of income in the Czech Republic in years 2000-2018



Source: The Czech Statistical Office, Own elaboration

4.2 One equation model

In case of one-equation model there are formulated assumptions based on economic theory and afterwards, the economic and econometric model are constructed. Data set is presented and the parameters are estimated using Ordinary Least Square Method (OLSM) in both SW GRETL and Microsoft Excel, followed by economic, statistic and econometric verification. As a last step an application of the model is done.

4.2.1 Economic model

Assumptions

The aim of this thesis is to analyse, verify and express econometric model on the topic of *Consumption of Pork Meat in the Czech Republic*. Therefore, the dependent variable of the model is Consumption of pork meat, consumed in the territory of the Czech Republic. Based on economic theory, the independent variables were chosen. Originally, the idea was to compose the model of Consumer price of pork meat (in the Czech Republic), Consumption of beef, Consumption of poultry as the main substitutes of pork meat and Income in the Czech Republic as the last explanatory variable.

The first assumption would be the influence of consumer price of pork meat. If the price of this commodity is increased, we assume that the consumption of pork meat will decrease as the consumer might consider this good out of his budget limit and prefer other substitutional good instead.

$$\uparrow \boldsymbol{CP\ PM} \ \Rightarrow \downarrow \boldsymbol{C\ PM}$$

The next expectation based on the theory of goods substitution is that if the consumption of beef in the Czech Republic decreases the consumption of pork rises. The same applies for poultry (chicken meat). This assumption results from collected data that had shown the most consumed kind of meats in the Czech Republic during the observed period that are right mentioned pork, chicken and beef. Therefore, those were appointed as suitable substitutes for a model.

$$\downarrow \boldsymbol{C\ BM} \ \Rightarrow \uparrow \boldsymbol{C\ PM}$$

$$\downarrow \boldsymbol{C\ ChM} \ \Rightarrow \uparrow \boldsymbol{C\ PM}$$

And for the last variable, in case the average level of income in the Czech Republic goes up, we expect the consumption of pork meat will also increase. This statement is based on assumption that when the consumers budget increases, he or she can effort to buy or consume more of the goods up to the level of saturation when consumer has enough of certain good and prefer to buy another type of good on the top of this good and instead of more of this good.

$$\uparrow \boldsymbol{In} \ \Rightarrow \uparrow \boldsymbol{C\ PM}$$

However, these were later proven as not that suitable for the model as the further analysis in Gretl software had shown the quality of the originally intended linear model was only 49.55%. Even the form of power function was considered and verified, nevertheless, the quality of the model was even worse. Only 47.31%. As it turned out, only the constant was statistically significant reaching the significance level of 0.01 (***), whether the consumption of beef and income were of significance level 0.1 (*). Subsequently, several analyses with different combinations of these variables and also multicollinearity eliminations were run through the Gretl software where the quality of the model was ranking between values of 30.28 to already mentioned 49.55%, which are all rather a poorly explained models by the explanatory variables. However, in some models even a consumption of poultry shown level of significance of 0.05 (**). Anyways, in those models only the constant was significant again but no other variable and furthermore, the quality of model was very bad.

Therefore, some of the originally selected variables were replaced by a newly appointed variables for the model that are more or less alternatives to the previous variables. The currently considered equivalent of the model of *Consumption of the Pork meat in the Czech Republic* in selected time frame consists of Consumer price of pork meat (in the Czech Republic), Consumer price of beef, Consumer price of poultry as the prices of main substitutes of pork meat and Income in the Czech Republic remains as the last explanatory variable.

Assumptions for the exchanged variables are still based on the theory of goods substitution and its prices. These are called cross-prices as the consumption of certain product is affected by consumer price of another product. The expectations are that if the consumer price of beef in the Czech Republic decreases the consumption of pork decreases as well, pointing out the direct proportion, as the consumers are most likely to choose more inexpensive commodity to purchase and consume. The same applies for poultry (chicken meat). This assumption again results from collected data that shown the most consumed kind of meats in the Czech Republic during the observed period that are next to the examined pork, the chicken and beef. Therefore, those were appointed and remained as suitable substitutes for a model but this time its prices are included in the model.

$$\downarrow \boldsymbol{CP\ BM} \ \Rightarrow \downarrow \boldsymbol{C\ PM}$$

$$\downarrow \boldsymbol{CP\ ChM} \ \Rightarrow \downarrow \boldsymbol{C\ PM}$$

Theoretically, there could be a next variable in the model with an impact on the consumption of pork meat that would be considered as a complement. That would mean that if the price of the complement grows, we expect the consumption of pork meat to go down. In case of pork meat there is no direct complement. If the complement would be contemplated, it could be a side dish but as one of the products that could be used as a side dish (for example potatoes) would go up, consumer would easily choose another substitute (such as rice or bread or some kind of vegetables). Therefore, this variable has not been selected for this model.

Economic model

$$\boldsymbol{y_{1t} = f(x_{1t}, x_{2t}, x_{3t}, x_{4t})}$$

Where:

- $\boldsymbol{y_{1t}}$ is Consumption of Pork Meat (C PM)
- $\boldsymbol{x_{1t}}$ stands for Consumer price of Pork Meat (CP PM)
- $\boldsymbol{x_{2t}}$ expresses Consumer price of Beef Meat (CP BM)
- $\boldsymbol{x_{3t}}$ represents Consumer price of Chicken Meat (CP ChM)
- $\boldsymbol{x_{4t}}$ is Income (In)

Therefore, in our case it would look like the following function:

$$\boldsymbol{C\ PM = f(CP\ PM, CP\ BM, CP\ ChM, In)}$$

Anyhow, considering modification of the model that is going to be explained in chapter 1.*2.5 of Model verification*, subchapter of *Statistical verification*, the Economic model is going to be a function of Consumer price of Beef and Income:

$$\boldsymbol{y_{1t} = f(x_{1t}, x_{2t})}$$

Where:

- $\boldsymbol{y_{1t}}$ is Consumption of Pork Meat (C PM)
- $\boldsymbol{x_{1t}}$ stands for Consumer price of Beef Meat (CP BM))
- $\boldsymbol{x_{2t}}$ expresses Income (In)

And thus:

$$\boldsymbol{C\ PM = f(CP\ BM, In)}$$

4.2.2 Econometric model

Standard econometric model is represented by an equation in linear form:

$$y_{1t} = \gamma_{11}x_{1t} + \gamma_{12}x_{2t} + \gamma_{13}x_{3t} + \gamma_{14}x_{4t} + \gamma_{15}x_{5t} + \varepsilon_{1t}$$

Where:

- y_{1t} = Explained variable
- x_{1t} = Constant
- $x_{2t} - x_{5t}$ = Explanatory variables
- $\gamma_1 - \gamma_5$ = Structural parameters of explanatory variables
- u_t = Residuals or stochastic parameter

For pork meat consumption econometric modelling it was considered as a linear as a power function. In the end, a power function was selected. As Gujarati (2003) explains, dependent variables rate of change remains constant for unit change explanatory variables in the classical linear regression models. Slope curve is constant. The variables and parameters of the regression model may be linear, but the crucial factor is linearity of parameters here.

If the function of selected model for estimation of regression function does not have linear parameters, it is necessary to linearize the whole model. If the power functions are being used for formulation and estimation of models, the process of linearization or equivalently logarithmic transformation must be employed. (Gujarati, 2003)

Therefore, to be able to estimate the individual parameters of chosen variables, there is a need to linearize the model first. The output is a linear form of power function. Then it is possible to apply and use ordinary least square method to investigate the relationships between variables using observations from the year 2000 to 2018. The model and process of linearization looks as follows:

$$y_{1t} = y_1 \, x_{1t} \, x_{2t}^{\gamma_2} \, x_{3t}^{\gamma_3} \, x_{4t}^{\gamma_4} \, x_{5t}^{\gamma_5} \, u_t$$

$$ln\, y_{1t} = ln\, \gamma_{11} + \gamma_{12}\, ln\, x_{2t} + \gamma_{13}\, ln\, x_{3t} + \gamma_{14}\, ln\, x_{4t} + \gamma_{15}\, ln\, x_{5t} + ln\, u_t$$

Where:

- $\boldsymbol{y_{1t}}$ = Consumption of Pork Meat (C PM)
- $\boldsymbol{x_{1t}}$ = Unit vector (UV) = u_{1t}= Intercept
- $\boldsymbol{x_{2t}}$ = Consumer price of Pork Meat (CP PM)
- $\boldsymbol{x_{3t}}$ = Consumer price of Beef Meat (CP BM)
- $\boldsymbol{x_{4t}}$ = Consumer price of Chicken Meat (CP ChM)
- $\boldsymbol{x_{5t}}$ = Income (In)
- $\boldsymbol{\varepsilon_{1t}}$ = Error Term (Residuals)

Declaration of variables and units

Again, considering the necessary changes in the model (explained in chapter *4.2.5 of Model verification*, subchapter of *Statistical verification*) the final variables present in the Econometric model were appointed as:

- $\boldsymbol{y_{1t}}$ = Consumption of Pork Meat (C PM) … kg/year/capita
- $\boldsymbol{x_{1t}}$ = Unit vector (UV) = u_{1t}= Intercept
- $\boldsymbol{x_{2t}}$ = Consumer price of Beef Meat (CP BM) … CZK/kg
- $\boldsymbol{x_{3t}}$ = Income (In)… thousand CZK (Net income per household)
- $\boldsymbol{x_{4t}}$ = Time vector (TV) = ensure dynamization of the model
- $\boldsymbol{\varepsilon_{1t}}$ = Error Term (Residuals)

As the model was linearized, the equation was transferred into a linear form of the power function and therefore, it is prepared for application of Ordinary Least Square Method (OLSM) used for the parameters estimation. Estimated parameter γ_1 is by backward estimation recalculated and substituted to the original equation, together with other parameters γ_2, γ_3 and γ_4.

The Latin phrase ceteris paribus is commonly used for the concept where the estimated parameters γ_2 to γ_4 are interpreted as coefficients of elasticity of dependent variable y towards of change of corresponding independent variable x holding all other explanatory variables constant. (Gujarati, 2003) So, in this model these would be coefficients of direct price elasticities.

4.2.3 Data

There are two basic types of data. It is categorized as primary and secondary data according to the method of collecting, gathering and processing of this information in context. Primary data are obtained by researcher, whether in form of survey of interview or semi-interview. Researcher collects own data from satisfactory and unbiased sample of people. This sample should be random. If the sample size is big enough, it can represent the whole population and be applied to it. Then there are secondary data, that are already collected by another researcher for whatever purpose. These data are provided with simple description of what do they represent. What does these values mean and when it was collected. These kinds of data can be then used by another researcher for purposes of his or her own research.

Data Table

Data observable in *tables 1* and *2* in *appendix* are secondary data that were collected from The Czech Statistical Office. The model is based on annual data, which represent time series with 19 observations from year 2000 until 2018.

Meanwhile in *Table 1*, there are data intended for the original form of the model, in the *Table 2* there are data for the current form of the examined model of Consumption of Pork meat in the Czech Republic.

Summary statistics

The table below includes already actualized descriptive data such as mean, median, minimal, maximal value and standard deviation of variables of current form of the model to provide statistics summary.

Table 3: Summary Statistics

	y_{1t}	x_{1t}	x_{2t}	x_{3t}	x_{4t}	x_{5t}
Mean	41,52	92,45	135,40	59,78	22,20	41,52
Median	41,31	90,94	130,47	60,55	23,34	41,31
Minimum	40,33	81,02	106,79	44,30	13,22	40,33
Maximum	43,18	106,70	173,13	70,55	31,87	43,18
Standard deviation	0,80	8,52	21,57	7,45	5,14	0,80

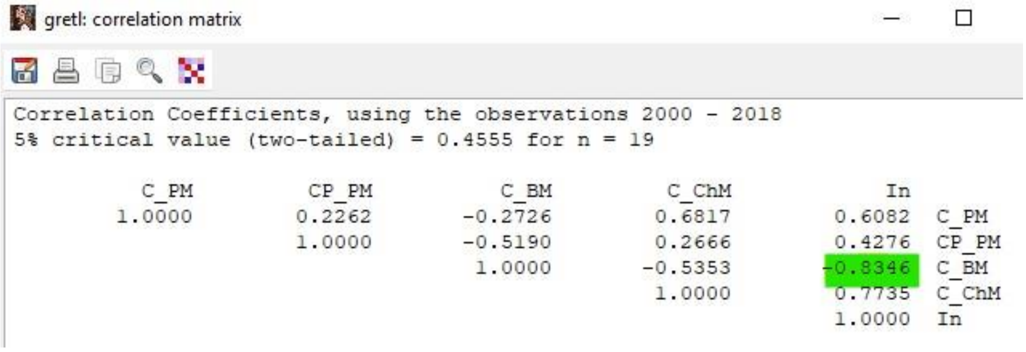
Source: The Czech Statistical Office, own calculations and elaboration

From the statistical data overview, it is observable that the average consumption of pork meat in the Czech Republic is 41.52 kg per capita per year. Middle value of this variable $\mathbf{y_{1t}}$ is 41.31 kilograms, minimal value is 40.33 kg and the maximum is 43.18 kg. The standard deviation is equal to square root of variance. In case of consumption of pork, the value is 0.80 kg/cap/year and shows how much are our values deviated from the average values. The same principle of interpretation can be applied also in case of other variables x_{1t}, x_{2t},$x_{3t,}$ x_{4t} and x_{5t}.

<u>Correlation Matrix</u>

In the original model, there is only one multicollinearity occurring in the correlation matrix, see *Picture 4* below. This means there is a value bigger than |0.8|. The multicollinearity is observable between exogenous variables *Consumption of Beef Meat* and *Income*. If there was another value greater than |0.8| but between *Consumption of Pork Meat* and any other variable, it would show significant relationship of dependent and independent variable, which would be good for the model.

Picture 4: Correlation Matrix on the first model version


gretl: correlation matrix

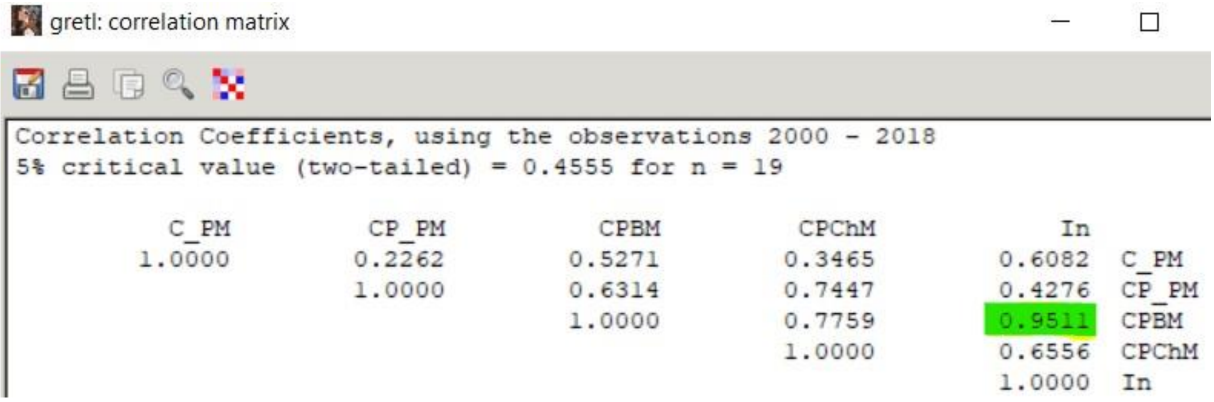
Correlation Coefficients, using the observations 2000 - 2018
5% critical value (two-tailed) = 0.4555 for n = 19

C_PM	CP_PM	C_BM	C_ChM	In	
1.0000	0.2262	-0.2726	0.6817	0.6082	C_PM
	1.0000	-0.5190	0.2666	0.4276	CP_PM
		1.0000	-0.5353	-0.8346	C_BM
			1.0000	0.7735	C_ChM
				1.0000	In

Source: Gretl SW

On the other hand, in the current version of the model there is also just one multicollinearity present in the correlation matrix and that is specifically between independent variables *Consumer price of Beef* and *Income*, as visible in *Picture 5* below. The paired correlation of 3rd and 5th exogenous variable is higher than 0.9.

Picture 5: Correlation Matrix on the current model version



gretl: correlation matrix

Correlation Coefficients, using the observations 2000 - 2018
5% critical value (two-tailed) = 0.4555 for n = 19

C_PM	CP_PM	CPBM	CPChM	In	
1.0000	0.2262	0.5271	0.3465	0.6082	C_PM
	1.0000	0.6314	0.7447	0.4276	CP_PM
		1.0000	0.7759	0.9511	CPBM
			1.0000	0.6556	CPChM
				1.0000	In

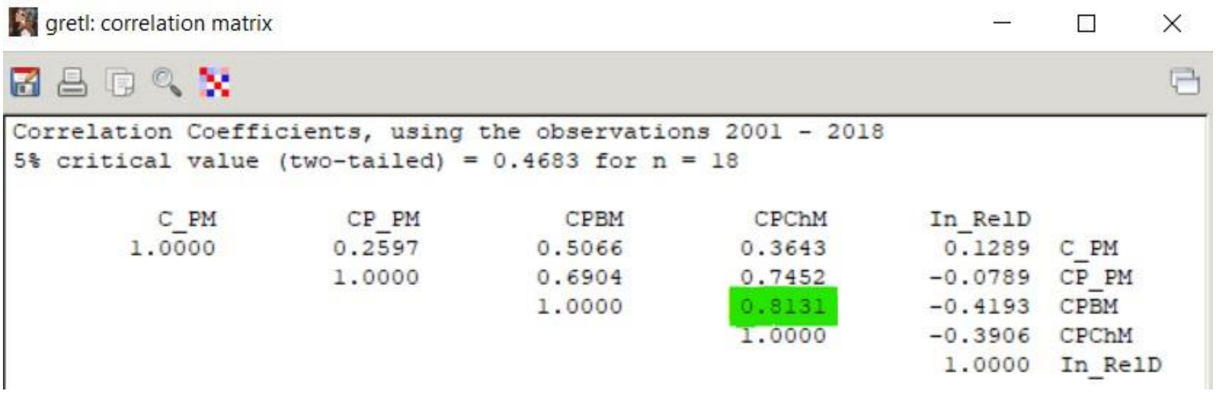
Source: Gretl SW

<u>Multicollinearity Elimination</u>

To solve the problem of multicollinearity, there are several different possible approaches of modification of the model that could be applied. One of the possible solutions could be whether to omit one of the variables from the model but that is rather a not recommended option. Another operation how to fix a multicollinearity could be by transformation of data using the 1st or Relative difference. Other ways are an inclusion of a dummy variable, extension of time series or simply to not eliminate the multicollinearity. That might cause to bigger inaccuracy as is insignificancy of the parameters for example, but it is not a wrong procedure.

Regarding our model of Pork meat consumption, firstly, the time-series of Consumption of Beef Meat had been modified by using the 1st difference but as the further analysis in Gretl has shown, that our model needed some changes. Therefore, for the following model the usage of *relative difference* has been proven as a more suitable choice and moreover, that was applied on the time-series of *Income* this time.

Picture 6: Correlation Matrix after Multicollinearity elimination



gretl: correlation matrix

Correlation Coefficients, using the observations 2001 - 2018
5% critical value (two-tailed) = 0.4683 for n = 18

C_PM	CP_PM	CPBM	CPChM	In_RelD	
1.0000	0.2597	0.5066	0.3643	0.1289	C_PM
	1.0000	0.6904	0.7452	-0.0789	CP_PM
		1.0000	0.8131	-0.4193	CPBM
			1.0000	-0.3906	CPChM
				1.0000	In_RelD

Source: Gretl SW

Although, the multicollinearity between exogenous variables *Consumer price of Beef* and *Income* was eliminated, as we can observe in the *Picture 6* above, new multicollinearity occurred, this time between independent variables *Consumer price of Beef* and *Consumer price of Chicken Meat*. This multicollinearity is going to be pardon for now and the following analysis is going to continue with newly elaborated data set, visible in *Picture 7*. There can be observed a reduction in number of observations of the time-series in the incurred data set. As the multicollinearity was solved by relative differences, that are calculated as a current year divided by the previous year, there is a loss of the base year 2000. Thus, the originated data set consists of 17 observations from year 2001 to year 2018 from now on.

Picture 7: Data after Multicollinearity elimination

	C_PM	CP_PM	CPBM	CPChM	In_RelD
2000	40.90	97.635	114.205	61.65	
2001	40.90	103.070	106.785	60.55	1.087677
2002	40.90	81.195	107.195	46.23	1.079705
2003	41.50	84.970	107.025	53.60	1.058361
2004	41.10	90.935	114.080	51.80	1.063055
2005	41.50	84.645	119.065	51.60	1.050269
2006	40.70	84.655	122.785	44.30	1.065526
2007	42.00	82.785	124.275	61.47	1.072189
2008	41.31	87.270	129.315	58.99	1.078017
2009	40.90	84.890	132.135	56.18	1.033286
2010	41.59	81.015	130.465	58.63	1.022276
2011	42.07	87.775	138.380	58.49	1.024765
2012	41.29	99.180	154.670	65.52	1.025026
2013	40.33	102.505	157.285	69.63	0.998723
2014	40.72	97.665	156.335	70.55	1.029279
2015	42.90	93.570	155.615	66.30	1.031939
2016	42.84	103.245	161.765	64.87	1.044113
2017	42.34	106.700	168.160	67.64	1.067497
2018	43.18	102.815	173.125	67.74	1.075241

Source: Gretl SW

4.2.4 Parameters' Estimation (using OLSM in Gretl SW)

Parameters were both processed and estimated in software Gretl and Excel, where the significance level for econometric modelling was determined as α = 0.05. The relationship between selected variables was examined using Ordinary least square method. The essence of Ordinary Least Square method consists in finding parameters that minimize the sum of squared errors of residuals, using the formula:

$$\boldsymbol{\gamma} = (\boldsymbol{X}^{\boldsymbol{T}} * \boldsymbol{X})^{-\mathbf{1}} * \boldsymbol{X}^{\boldsymbol{T}} * \boldsymbol{Y}$$

However, as there was a problem with multicollinearity, data set had to be modified first and then the parameters of model could been estimated.

After the careful consideration of form of equation choice, the power function was selected as the most suitable choice for the model. Therefore, as described in the chapter *4.2.2. Econometric model* the function needed to be transferred into its linear form using the linearization procedure that uses natural logarithms of individual variables of the model. To utilize this process, it was necessary to eliminate the multicollinearity by relative differences so the natural logarithms could been applied as the natural logarithms does not exist for negative values. For that reason, the 1st differences of variable could not been used for the fixation of multicollinearity in this particular case.

The results of the final parameter estimation of the final form of the model are shown in the *Picture 8* below.

Picture 8: Estimation of parameters

Model 4: OLS, using observations 2001-2018 (T = 18)
Dependent variable: l_C_PM

	coefficient	std. error	t-ratio	p-value	
const	5.17820	0.515723	10.04	8.88e-08	***
l_CPBM	-0.326241	0.112062	-2.911	0.0114	**
l_In_RelD	0.330470	0.136973	2.413	0.0301	**
time	0.0126275	0.00339268	3.722	0.0023	***

Source: Gretl SW

However, the choice of the power function cannot be forgotten. After the process of linearization follows the process of subsequent de-linearization. As the estimated values highlighted next to the individual independent variables represents their final parameters, the value observable next to the constant needs to be transfer using the Euler number powered on this specific value. The calculation looks like:

$$e^{5.18} = 177.37$$

Finally, all the estimated parameters are going to be inserted back to the original function and by doing so, the process of de-linearization is completed. Thus, the general form of our final econometric model with all estimated parameters would is represented by following equation:

$$\boldsymbol{y_{1t} = 177.37\ x_{2t}^{-0.33}\ x_{3t}^{0.33}\ x_{4t}^{0.01}\ u_t}$$

There were important changes of the model structure deducted that are going to be step by step demonstrated and defended and in following chapter *1.2.5 of Model verification – Statistical and Economic verification.*

4.2.5 Model verification

Verification of the model consists of four major steps. That is of Mathematical verification, Statistical verification followed by Economic verification and Econometric verification as the last part of this verification process.

In previous chapter *1.2.4 Estimation of parameters* was already published the final scheme of the model that is going to be furtherly verified in this chapter and used for application of the model in following one. The process of how was this model deducted is going to be described and successively explained in subchapters of Statistical and Economic verification of the model, as mentioned before.

Mathematical verification

Mathematical verification represents the first and the simplest step of all following verifications. The average values of each element are inserted into the equation. The desired result of mathematical verification is that the left side of the equation is equal to the right side. Error term is equal to zero. This verification is done automatically by software Gretl and therefore, it will not be mentioned in following chapters anymore.

Statistical verification

In the statistical verification, we use statistical tests to check if the estimated parameters are statistically significant (Gama) and test the goodness of fit is also done. The statistical verification can be calculated in Microsoft Excel software but the Gretl software provides the outputs of this verification as well.

To test if the influence if explanatory variable influences explained variable the ***t-test*** is used for every single parameter. This procedure is composed of steps presented below.

Firstly, the null and alternative ***hypotheses*** are stated (H_0: $\gamma = 0$ and H_1:$\gamma \neq 0$).

As a second step, the ***Adjusted Residual Sum of Squares*** (*RSS with bar*) also representing *Variance of residuals* S_u^2 is calculated. In a third step, the *inverse matrix* X^{-1} is needed, especially its leading diagonal. The individual values of this Covariance matrix are multiplied by Residual sum of squares and by this calculation, the ***Variance of estimated parameters*** is obtained. In a fourth step, the calculation of ***Error of parameter*** is done as a root square of Variance of estimated parameters and at last, the t-value is calculated. Now, the statistical verification of individual parameters can be realized by comparison of the calculated t-value with table value, also called t-tab. If the t-value is greater than t-tab, the null hypothesis is being rejected and therefore it is proven that the particular parameter is significant, based on criteria:

$$\boldsymbol{t_{\,val} > t_{tab} => reject\ H_0}$$

After the check of all parameter's significance level, it is necessary to evaluate fit of the whole model. For that, correlation coefficient and coefficient of determination is used.

The results of the final model are presented in *Picture 9* as an output of Gretl.

Picture 9: Statistical verification of the model

```
Model 4: OLS, using observations 2001-2018 (T = 18)
Dependent variable: l_C_PM

               coefficient   std. error   t-ratio   p-value
  ----------------------------------------------------------
  const         5.17820      0.515723     10.04     8.88e-08 ***
  l_CPBM       -0.326241     0.112062     -2.911    0.0114   **
  l_In_RelD     0.330470     0.136973      2.413    0.0301   **
  time          0.0126275    0.00339268    3.722    0.0023   ***

Mean dependent var   3.726937   S.D. dependent var   0.019892
Sum squared resid    0.002038   S.E. of regression   0.012067
R-squared            0.696980   Adjusted R-squared   0.632047
F(3, 14)             10.73386   P-value(F)           0.000632
Log-likelihood       56.23262   Akaike criterion    -104.4652
Schwarz criterion   -100.9037   Hannan-Quinn        -103.9741
rho                 -0.205319   Durbin-Watson        2.388447

Log-likelihood for C_PM = -10.8523
```

Source: SW Gretl

It is observable that in both softwares, all of the parameters are statistically significant. The highest level of statistical significance 0.1 (***) has UV vector that is also an intercept or a constant and Time vector. The other parameters are of statistical significance level 0.5 demonstrated by two stars. The coefficient of determination (R^2) is 0.70. That means that 70% of variability of the dependent variable are explained by the model, or in another words, that from 70% the changes in explained variable are caused by changes in explanatory variables, which is quite good. Furthermore, the Adjusted R-squared ($\overline{R^2}$) is 0.63 and that reflexes 63%

of explained model by independent variables with respect to the number of variables. Also, p-value confirms the significance of the whole model, as it is lower than alpha level (0.0006 < 0.01). Thus, this model is also good statistically due to its significance.

The final scheme of the model was described and now, the process of obtaining this model is going to be described and commented from statistical verification perspective. Several combinations of intended variables were verified, however, power functions where the time vector is included always certifies as models of better-quality. That can be observable in following tables below.

At first, models composed of all original variables were tested and as can be visible. There is a comparison of four models. Two are in linear form and two in form of power function. Addition of time trade variable was decided as the consumption of pork seems to have significant dependence on time. In all models of *Table 4* there is significant constant, consumer price of beef, income and time vector, if it is included. Based on coefficient of determination R^2 we observe growth in quality of model in form of power function with time vector and therefore, the aim is to increase the quality even more.

Table 4: Statistical verification of selected models

	C_PM	**Linear Function**					**Power Function**			
	variables	***parameters***	***signif.***	***p-val***	***R^2***		***parameters***	***signif.***	***p-val***	***R^2***
1	constant	20.89	**	0.06	31.18%	3	3.46	***	0.065	30.76%
	CP_PM	-0.04					-0.09			
	CP_BM	0.03	**				0.1	**		
	CP_ChM	0.02					0.04			
	In_RelDiff	17.92	**				0.47	**		
2	constant	32.89	***	0,01	54.35%	4	5.21	***	0.007	57.70%
	CP_PM	0.02					0.008			
	CP_BM	-0.11	*				-0.35	**		
	CP_ChM	-0.0001					0.01			
	In_RelDiff	15.23	**				0.32	*		
	time	0.54	**				0.01	**		

Source: Gretl SW, Own elaboration

Therefore, the subject of further verification were models in form of power function with time vector included. Gradually, the variables that are both statistically and economically insignificant were excluded from the model. Statistical significance is represented by p-value of each parameter and is also marked by stars in Gretel software (the more stars parameter has, the more significant it is, whereas the maximum are three stars) whether the economic significance depends on the value of parameter (the smaller value, the smaller significance).

Thereby there is an observable increase in coefficient of determination R^2 that is an indicator of model quality with respect to contained variables and their relevance to the model. Also, p-value of the model is lower than alpha which signalise confirmation of the quality of the model. As it is demonstrated in *Table 5* by omitting Consumer price of pork meat does not cause a radical change in values of parameters that is another confirmation of insignificancy of this variable for the model.

Table 5: Statistical verification of selected models

	C_PM	**Power Function**			
	variables	***parameters***	***significance***	***p-val.***	***R^2***
5	constant	5.24	***	0.002	60.71%
	CP_PM	0.02			
	CP_BM	-0.36	**		
	In_RelDiff	0.31	*		
	time	0.01	***		
6	constant	5.18	***	0.0006	63.20%
	CP_BM	-0.33	**		
	In_RelDiff	0.33	**		
	time	0.13	***		

Source: Gretl SW, own elaboration

Economic verification

In this part, we proceed economic verification to see if the signs of structure parameters are agreed with our economic theory. From the equation we can determine the relationship between dependent and independent variable by the direction of the sign of the estimated parameter (negative or positive) and the strength of relationship is shown by the value of estimated parameter. Interpretation of our variables is as follows:

- +177.37 represent an intercept, C PM in kg/year/capita ⇒ Positive relationship
  - ⇒ constant, it shows the consumption of pork meat free from the influence of the other factors (e.g. if the other factors are equal to 0, the consumption of pork meat would be 177.37 kilograms per year per capita which means that there will not be zero consumption of pork meat)
  - ⇒ consumption should be positive, and ours is positive… ✓

- -0.33= CP BM ⇒ if CP BM ↑ by 1 unit ⇒ C PM ↓ by 0.33 kg/year/capita

  ⇒ beef is assumed to be a substitute to the pork meat. Therefore, if the price of substitutional good increase, the consumption of examined good should increase so this relationship should have been positive; if CP BM ↑ ⇒ C CP ↑ ⇒ so this is not the best finding for our model, however, it might be due to the preferences of consumers which cannot be economically explained and then there are other factors such as age, education, tradition, religion or place of living. Also, the share of beef has been continuously rising over the past couple of years.…

- 0.33 = In ⇒ if In ↑ by 1 unit ⇒ C PM ↑ by 0.33 kg/year/capita

  ⇒ based on economic theory the relationship between income and consumption should be positive (In ↑ ⇒ C PM ↑) as the more money consumers have, the more product they can afford and consume until it reaches the level of saturation and thus, this result verifies our presumption

- 0.01 = TV (time trend or time vector) ⇒ C PM ↑ by 0.01 kg/year/capita

  ⇒ the quantity of consumed pork is going up by roughly 0.01 kg every year and thus, this assumption was satisfied

The economic verification therefore showed us that the model is quite good.

<u>Econometric verification</u>

Econometric verification will be done through test of Autocorrelation, Heteroscedasticity and Normality of residuals, to check conditions necessary for following application of the model.

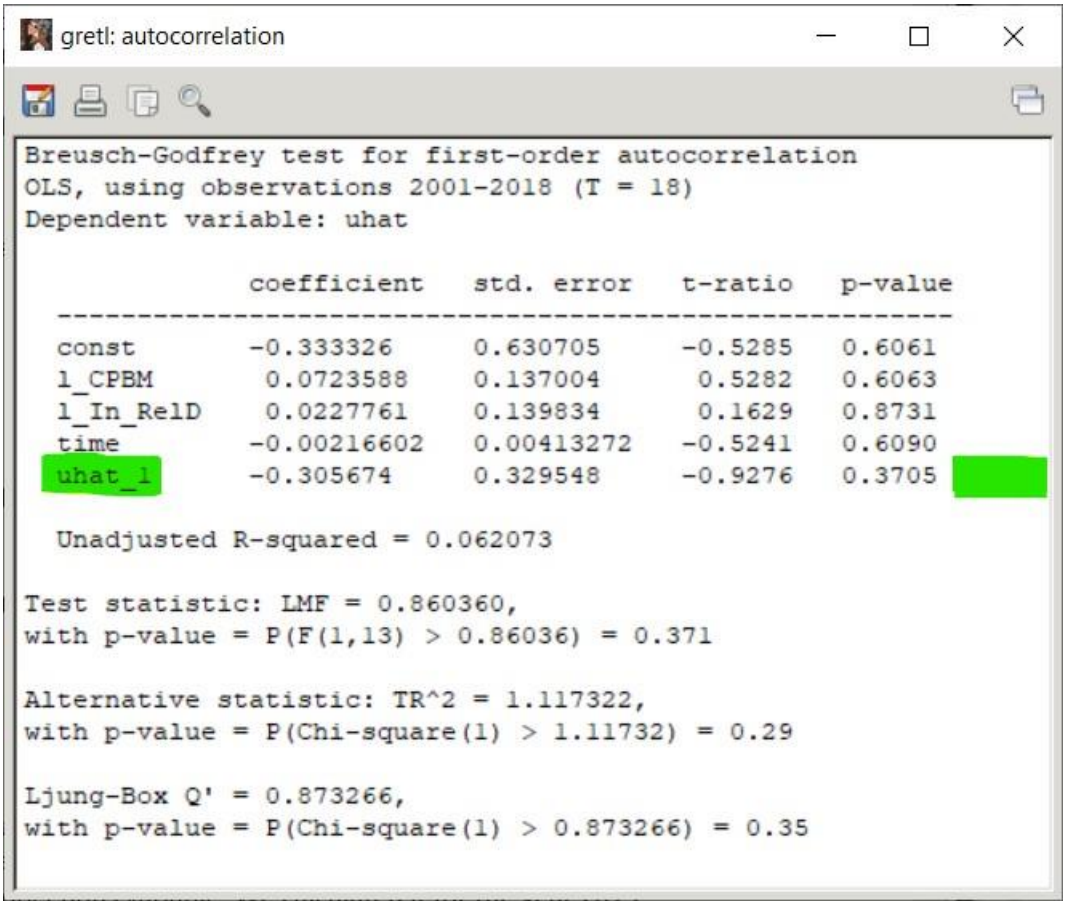
Autocorrelation

Autocorrelation expresses the level of dependency between residuals. It might be caused by exclusion of relevant variable from the model, inappropriate dynamics of the model, by a choice of inappropriate analytic function form or by inertia of the data. That might lead to consistent and unbiased estimates, however, not the best. Also, it tells us the standard errors of parameters are misleading which might cause problems with statistical verification and higher R^2. For that, two opposite hypotheses are defined. Null hypothesis claim, there is NO autocorrelation present, whether alternative hypothesis claims there is an autocorrelation present.

$$H_0:\ \rho = 0\ \Rightarrow Absence\ of\ Autocorrelation$$
$$H_A: \rho \neq 0\ \Rightarrow Presence\ of\ Autocorrelation$$

To check the autocorrelation of the first order, the Durbin-Watson (DW) test is used. The interval is <0;4> with significance level 5%. According to degrees of freedom and number of variables the table values are found and therefore the lower limit is 0.9331 and the upper one is 1.69614 for this model. The value of DW is 2.388447 with p-value = 0.000632. As this value is greater than both, lower and upper limit, we can claim that there is no positive autocorrelation present. Interval <D_u;4> means negative correlation. Anyways, as verified by Gretl software, there is no significant autocorrelation present in the model as visible in *Picture 10*, if there was a significant autocorrelation present, there would be sign of significance next to the last variable in form of stars. As there are none, the autocorrelation is insignificant.

Picture 10: Test of Autocorrelation




```
Breusch-Godfrey test for first-order autocorrelation
OLS, using observations 2001-2018 (T = 18)
Dependent variable: uhat

                 coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------------
  const          -0.333326     0.630705     -0.5285   0.6061
  l_CPBM          0.0723588    0.137004      0.5282   0.6063
  l_In_RelD       0.0227761    0.139834      0.1629   0.8731
  time           -0.00216602   0.00413272   -0.5241   0.6090
  uhat_1         -0.305674     0.329548     -0.9276   0.3705

  Unadjusted R-squared = 0.062073

Test statistic: LMF = 0.860360,
with p-value = P(F(1,13) > 0.86036) = 0.371

Alternative statistic: TR^2 = 1.117322,
with p-value = P(Chi-square(1) > 1.11732) = 0.29

Ljung-Box Q' = 0.873266,
with p-value = P(Chi-square(1) > 0.873266) = 0.35
```

Source: Gretl SW

Heteroscedasticity

Residuals that have the same finite variance are homoscedastic. If not, we have a problem with heteroscedasticity. The reason might be inclusion of irrelevant variable in the model or with usage of cross-sectional data or data categorization. Consequences are the same as in case of autocorrelation. Therefore, for testing of heteroscedasticity, we used *Breusch-Pagan test*. The hypotheses are stated first as:

H_0: There is no heteroscedasticity in the model. (p-val > α level)

H_A: There is heteroscedasticity in the model. (p-val < α level)

Picture 11:Test of Heteroskedasticity

gretl: LM test (heteroskedasticity)

```
Breusch-Pagan test for heteroskedasticity
OLS, using observations 2001-2018 (T = 18)
Dependent variable: scaled uhat^2

             coefficient   std. error   t-ratio   p-value
  ---------------------------------------------------------
  const      -37.9768      43.5902      -0.8712   0.3983
  l_CPBM       8.52061      9.47175      0.8996   0.3836
  l_In_RelD  -11.4825      11.5773      -0.9918   0.3381
  time        -0.214308     0.286758    -0.7473   0.4672

  Explained sum of squares = 4.26082

Test statistic: LM = 2.130410,
with p-value = P(Chi-square(3) > 2.130410) = 0.545785
```

Source: Gretl SW

As the result of the Breusch- Pagan test is p-value 0.546, which is bigger than α level 0.05, there is no heteroscedasticity in the model but homoscedasticity.

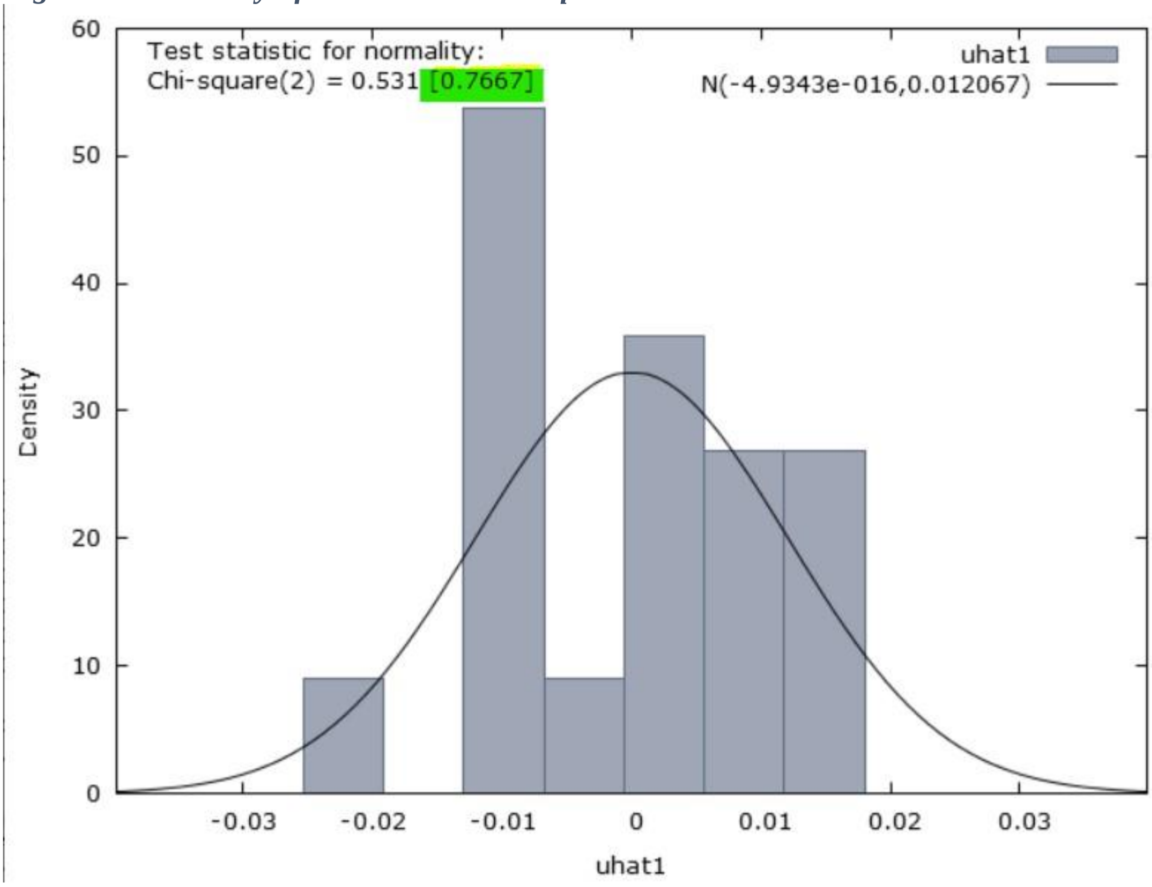
Normality Test of Residuals

Essence of this test is to verify, whether the residuals are normally distributed. Jarque-Bera test was used to test this normal distribution of residuals. The procedure is the same, there were hypotheses defined and based on the test result, the null hypothesis was accepted or rejected.

H_0: Residuals have normal dispersion. (p-val > α level)

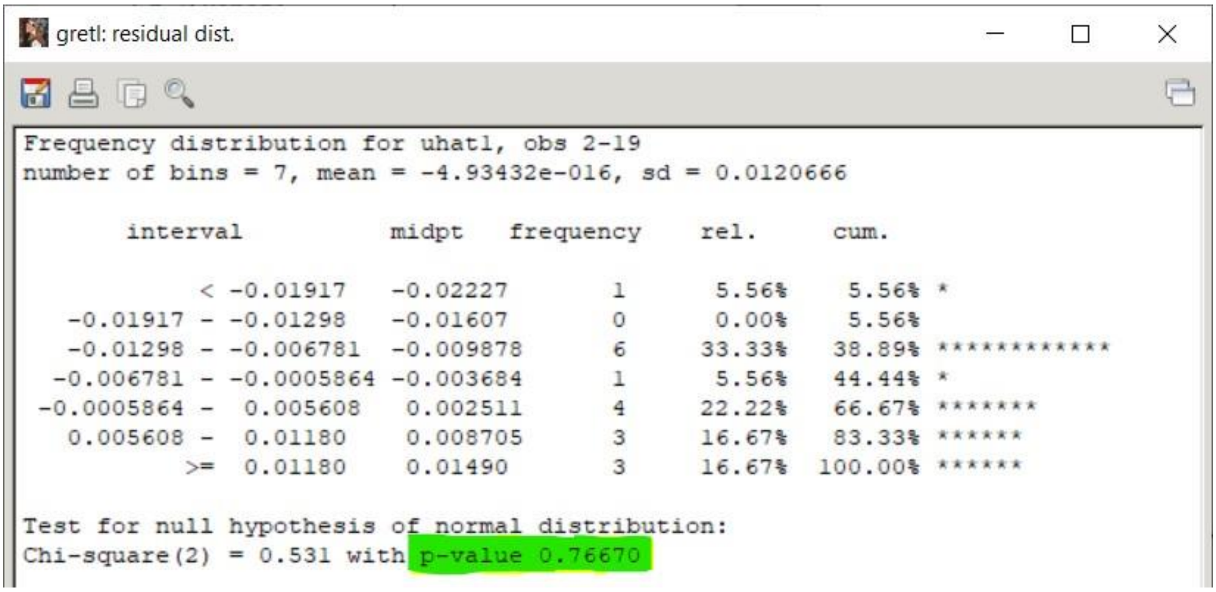
H_A: There is heteroscedasticity in the model. (p-val < α level)

Figure 6: Normality of Residuals – One-equation model



Source: Gretl SW

Picture 12: Normal distribution of Residuals



```
gretl: residual dist.

Frequency distribution for uhat1, obs 2-19
number of bins = 7, mean = -4.93432e-016, sd = 0.0120666

       interval          midpt   frequency    rel.     cum.

             < -0.01917   -0.02227      1      5.56%    5.56% *
   -0.01917 - -0.01298   -0.01607      0      0.00%    5.56%
   -0.01298 - -0.006781  -0.009878     6     33.33%   38.89% ************
  -0.006781 - -0.0005864 -0.003684     1      5.56%   44.44% *
 -0.0005864 -  0.005608   0.002511     4     22.22%   66.67% *******
   0.005608 -  0.01180    0.008705     3     16.67%   83.33% ******
           >=  0.01180    0.01490      3     16.67%  100.00% ******

Test for null hypothesis of normal distribution:
Chi-square(2) = 0.531 with p-value 0.76670
```

Source: Gretl SW

The result of normality test is p-value is 0.7667 (*Picture 12*), which is higher than the alpha level. Therefore, we accept the null hypothesis with conclusion that the residuals have normal dispersion. The normal distribution of residuals is also observable from *figure 6* above.

4.2.6 Model application

To allow comparability of each exogenous variables we need to express the intensity of exogenous variables on the endogenous variable as the elasticity. The values in the table represent the amount of influence of exogenous variables on endogenous variable. The advantage of power function is, that the calculation of Elasticities is not necessary as individual parameters (exponents) represents it.

Cross-Price Elasticity

The cross-price elasticity is an indicator of relationship between the consumption of examined commodity and price of substitutional commodity. Coefficient of cross-price elasticity of beef meat in our model is -0.33% < 1 so the relationship between pork meat consumption and price of its substitute in the Czech Republic is inelastic and these two commodities are not very close substitutes. Also, the relationship is negative, meaning that if the consumer price of beef increases by 1%, the consumption of pork meat decreases by 0.33%. Even though the number is really low, its influence is rather highly significant, and the change might be slightly noticeable.

Income Elasticity

Income elasticity shows dependency of the examined commodity on average of monthly income. In our model the coefficient of dependency of pork meat consumption on income in the Czech Republic is 0.33% which is again inelastic. The relationship is positive and therefore, if income grows by 1%, the consumption of pork increases by 0.33%. This elasticity is inelastic which typically corresponds to necessary goods.

To conclude it, the endogenous variable is significantly influenced by all of the exogenous variables.

Scenarios' simulation

Our model is quite good for forecasting of future trend, as the verifications showed that the only single variable is against the economic theory. Perhaps some important factor influencing the whole model was omitted or the factors included in the model were simply wrongly chosen. Still, if there would be a prediction made out of this model, it could look like this:

Let's say the consumer price of beef would increase by 15% in year 2019 and all other variables would remain constant. It would be calculated as 173.125*1.15 = 199.094

$$\hat{y}_{1(2019)} = 177.36 * 199.09^{-0.33} * 1.08^{0.33} * 18^{0.01} = 32.64$$

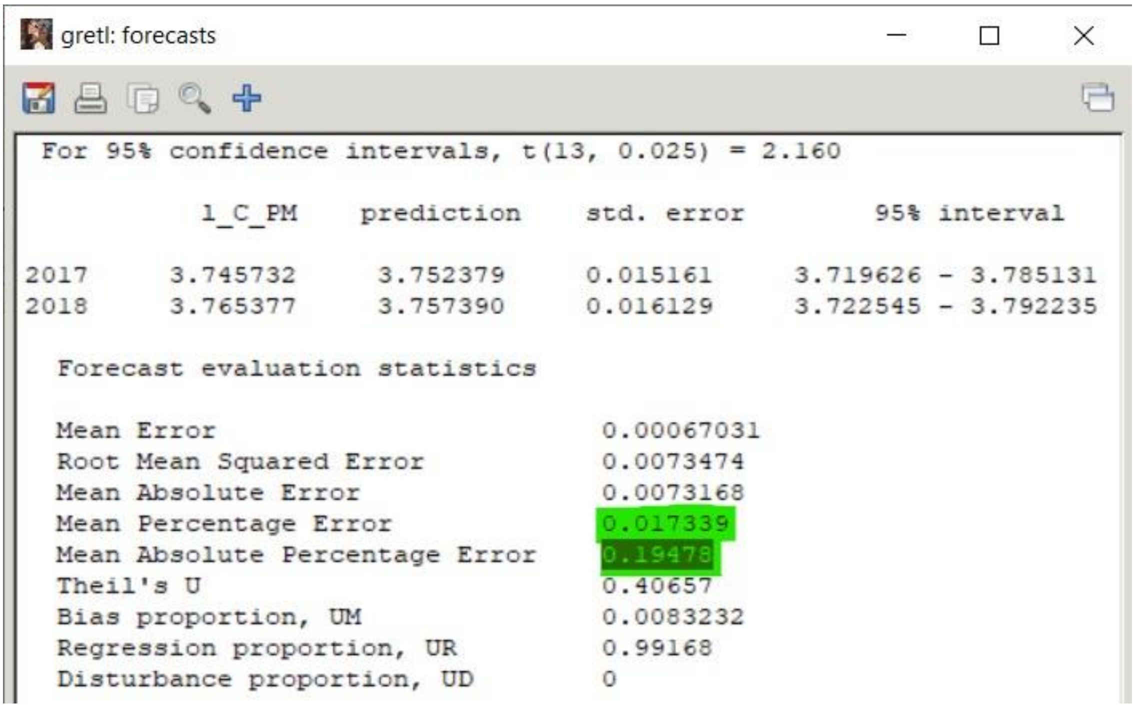
That is a drop in consumption of pork meat from 43.18 to 32.64 (decrease by 32.29%). That goes along with the value of the estimated parameter, that also expresses the elasticity and we can see, the number corresponds.

Ex-post prognosis

The principal of this prognosis is to cover few last years in data set and make the prognosis to see, how it matches the actual data that are already known. If we just make a prediction of future years, there is no way how to verify correctness and thus, the quality of the forecast until the actual data are known. By this method, the immediate comparison is possible.

Let´s reduce out set range of the last year 2018. For the calculation of prognosis, the Gretl software is going to be used. The output is captured in following *Picture 13* showing both, the point and 95% interval prediction for pork meat consumption for year 2018.

Picture 13: Ex-post prognosis of Pork meat consumption for year 2018


gretl: forecasts

```
For 95% confidence intervals, t(13, 0.025) = 2.160

             l_C_PM    prediction    std. error        95% interval

2017       3.745732     3.752379     0.015161     3.719626 - 3.785131
2018       3.765377     3.757390     0.016129     3.722545 - 3.792235

  Forecast evaluation statistics

  Mean Error                           0.00067031
  Root Mean Squared Error              0.0073474
  Mean Absolute Error                  0.0073168
  Mean Percentage Error                0.017339
  Mean Absolute Percentage Error       0.19478
  Theil's U                            0.40657
  Bias proportion, UM                  0.0083232
  Regression proportion, UR            0.99168
  Disturbance proportion, UD           0
```

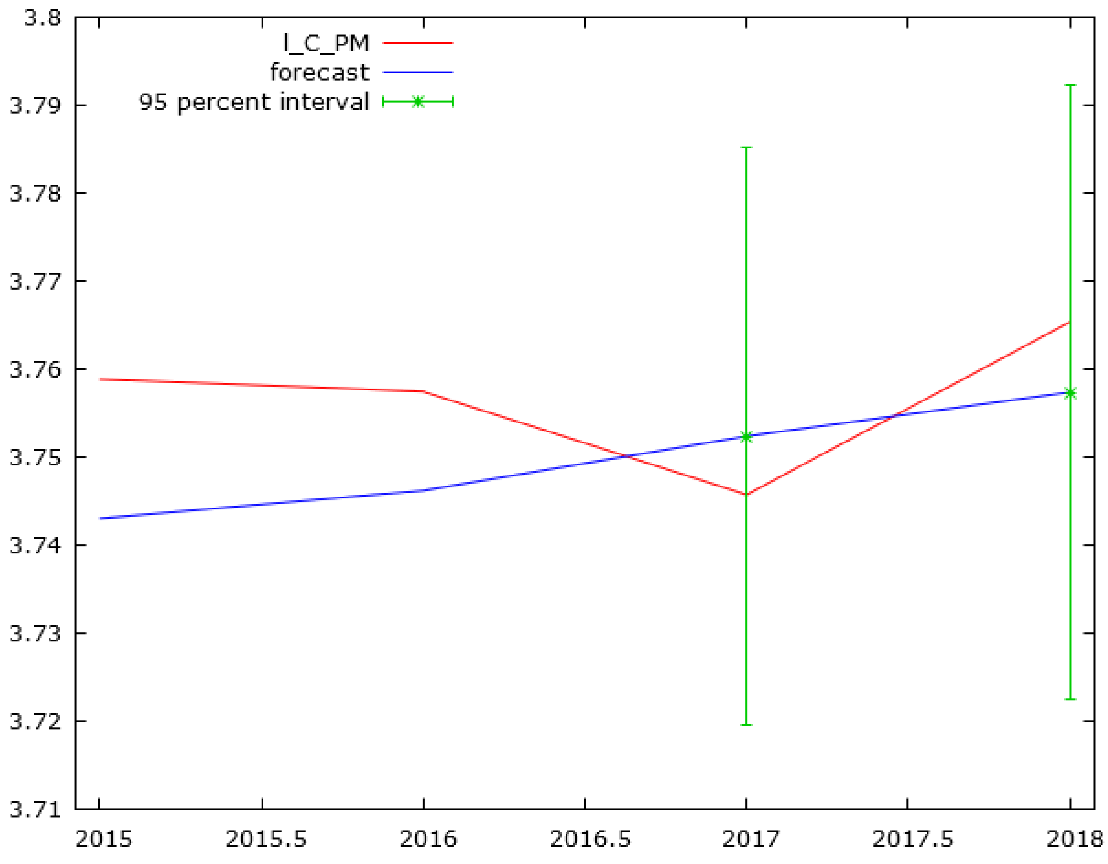
Source: Gretl SW

As we utilized a power function for our model, it is necessary to de-linearize the estimated value of Consumption of pork meat that was forecasted. For the calculation the Euler number was used:

$$e^{3.757390} = 42.8365$$

So actually, if this number is compared with our data set, we can see that the average pork meat consumption per capita in year 2018 was 43.18 kg. Therefore, we can claim, the prognosis is pretty accurate as the numbers are almost identical. Relative to our observations, our estimates are +0.017 away, which is the deviation and it means, our estimates are equivalent to 100.017% of the real observation (Mean percentage error in the *picture 13*). We can also observe, that overall, the forecast should be on average only 0.19% away from the actual observation that is represented by Mean absolute percentage error in the *picture 13*. The results are demonstrated in *figure 7*, where we can observe that the red line (real values of pork meat consumption are within the 95% confidence interval). Therefore, the model is recommendable for further predictions.

Figure 7: Graphical illustration of ex-post prognosis of CPM for 2018



Source: Gretl SW

4.3 Multiple-equations model

The procedure of multiple-equations model is similar. There were formulated assumptions based on economic theory, economic and econometric model. Set of data is presented. The identification of the model was proceeded and parameters were estimated using Two-Stage Least Square Method (TSLSM) in GRETL software. Afterwards the economic, statistic and econometric verification were applied and matrix Beta (B), Gama (Γ) and matrix of multipliers (M) were constructed. Final application of the model was done.

4.3.1 Economic model

Assumptions

Assumptions of second function:

- If consumption of pork meat grows, consumer price of pork meat increases

$$\uparrow \boldsymbol{C\ PM} \Rightarrow \downarrow \boldsymbol{CP\ PM}$$

- When number of pigs in the Czech Republic increases, consumer price of pork meat decreases

$$\uparrow \boldsymbol{NP} \Rightarrow \downarrow \boldsymbol{CP\ PM}$$

- If the number of slaughtered pigs increases, consumer price of pork meat decreases

$$\uparrow \boldsymbol{SP} \Rightarrow \downarrow \boldsymbol{CP\ C}$$

- In case that consumer price of rape seed grows, consumer price of pork meat increases

$$\uparrow \boldsymbol{CP\ RS} \Rightarrow \uparrow \boldsymbol{CP\ PM}$$

Economic model

The first function:

$$\boldsymbol{y_{1t}} = \boldsymbol{f}(\boldsymbol{x_{1t}}, \boldsymbol{x_{2t}})$$

Where:

- $\boldsymbol{y_{1t}}$ is Consumption of Pork Meat (C PM)
- $\boldsymbol{x_{1t}}$ stands for Consumer price of Beef Meat (CP BM))
- $\boldsymbol{x_{2t}}$ expresses Income (In)

And thus:

$$\boldsymbol{C\ PM} = \boldsymbol{f}(\boldsymbol{CP\ BM}, \boldsymbol{In})$$

The second function:

$$\boldsymbol{y_{2t}} = \boldsymbol{f}(\boldsymbol{y_{1t}}, \boldsymbol{x_{3t}}, \boldsymbol{x_{4t}}, \boldsymbol{x_{5t}})$$

Where:

- y_{2t} is Consumer price of Pork meat (CP PM)
- y_{1t} expresses Consumption of Pork meat (C PM)
- x_{3t} stands for Number of Pigs (NP)
- x_{4t} is Slaughtered Pigs (SP)
- x_{5t} represents Consumer Price of Rape Seed (CP RS)

Therefore, in our case it would look like the following function:

$$\boldsymbol{CP\ PM} = \boldsymbol{f}(\boldsymbol{C\ PM}, \boldsymbol{NP}, \boldsymbol{SP}, \boldsymbol{CP\ RS})$$

4.3.2 Econometric model

$$\boldsymbol{y_{1t} = \gamma_{11}x_{1t} + \gamma_{12}x_{2t} + \gamma_{13}x_{3t} + \gamma_{14}x_{4t} + \varepsilon_{1t}}$$

$$\boldsymbol{y_{2t} = \beta_{21}y_{1t} + \gamma_{21}x_{1t} + \gamma_{25}x_{5t} + \gamma_{26}x_{6t} + \gamma_{27}x_{7t} + \varepsilon_{2t}}$$

Declaration of variables and units

Where:

- $\boldsymbol{y_{1t}}$ = Consumption of Pork Meat (C PM) … kg/year/capita
- $\boldsymbol{y_{2t}}$ = Consumer price of Pork Meat (CP PM)
- $\boldsymbol{x_{1t}}$ = Unit vector (UV) = u_{1t}= Intercept
- $\boldsymbol{x_{2t}}$ = Consumer price of Beef Meat (CP BM) … CZK/kg
- $\boldsymbol{x_{3t}}$ = Income (In)… thousand CZK (Net income per household)
- $\boldsymbol{x_{4t}}$ = Time vector (TV) = ensure dynamization of the model
- $\boldsymbol{x_{5t}}$ = Number of Pigs (NP) …thousand heads
- $\boldsymbol{x_{6t}}$ = Slaughtered Pigs (SP)…thousand heads
- $\boldsymbol{x_{7t}}$ = Consumer Price of Rape Seed (CP RS) …CZK/kg
- $\boldsymbol{\varepsilon_{1t}}$ = Error Term (Residuals)

4.3.3 Data

Data observable in the table below are the secondary data by characteristic, meaning these were collected from The Czech Statistical Office. Starting observation is from year 2000 and the data was recorded annually until 2018. The time-series consists of 19 observations.

Data Table

Original data set of all variables included in the multiple-equations model, before the multicollinearity elimination, can be seen in *Table 6* in the *chapter 8* of *Appendix*.

Summary statistics

The table below includes descriptive data such as mean, median, minimal, maximal value and standard deviation of all variables included in the multi-equations model to provide statistics summary.

Table 7: Summary Statistics

	y_{1t}	y_{2t}	x_{1t}	x_{2t}	x_{3t}	x_{4t}	x_{5t}	x_{6t}	x_{7t}
Mean	41.52	10,00 45	1	135.40	22.20	10.00	2359.07	3317.56	8.52
Median	41.31	90.94	1	130.47	23.34	10.00	1971.42	3161.00	7.74
Minimum	40.33	81.02	1	106.79	13.22	1.00	1490.78	2309.69	6.63
Maximum	43.18	106.70	1	173.13	31.87	19.00	3687.97	4513.60	11.84
Standard deviation	0.80	8.52	0	21.57	5.14	5.48	790.15	763.28	1.89

Source: The Czech Statistical Office, own calculations and elaboration

From the statistical data overview, it is observable that the average consumer price of pork meat in the Czech Republic is CZK 92.45 per kilogram. Middle value of this variable $\mathbf{y_{2t}}$ is 90.94 Czech crowns, minimal value is CZK 81.02 and the maximum is 106.70 CZK/kg. The standard deviation is equal to square root of variance. In case of consumer price of pork, the value is 8.520 CZK/kg and shows how much are our values deviated from the average values. The same principle of interpretation can be applied to all of the other variables.

Correlation matrix and Multicollinearity elimination

Correlation matrix of the first equation is in chapter *4.2.3 Data set*. There is multicollinearity present, which was also confirmed in the multi-equations model. Therefore, we need to operate with the modified data. It was decided to use the same elimination method as previously.

Correlation matrix of the second equation is presented in the table below. We can observe there is a multicollinearity present between exogenous variables *Number of pigs*, *Slaughtered pigs* and *Consumer price of Rape Seed* (see *Picture 14*). However, considered the quality of the model, it was decided not to eliminate the multicollinearity between these three independent variables that might lead to increase in inaccuracy as insignificancy of the parameters for example, but it is not a wrong procedure.

Picture 14: Correlation matrix of the second function of Multiple-equations model

```
Correlation Coefficients, using the observations 2000 - 2018
5% critical value (two-tailed) = 0.4555 for n = 19

        CP_PM          C_PM            NP            SP         CP_RS
       1.0000        0.2262       -0.3848       -0.4933        0.5282  CP_PM
                     1.0000       -0.4469       -0.5074        0.3397  C_PM
                                   1.0000        0.9859       -0.8184  NP
                                                 1.0000       -0.8039  SP
                                                               1.0000  CP_RS
```

Source: Gretl SW

As a last step, correlation of all variables used in the model was checked and there was also multicollinearity discovered between variables *Consumer price of Beef, Number of pigs*, and *Slaughtered pigs*, as seen in *Picture 15* under. Once again, it was decided to leave these independent variables in present form even though it might lead to increase in inaccuracy such as insignificancy of the parameters, but it is not an incorrect procedure.

Picture 15: Correlation matrix of the multiple-equations model

```
Correlation Coefficients, using the observations 2001 - 2018
5% critical value (two-tailed) = 0.4683 for n = 18

         C_PM          CPBM       In_RelD         CP_PM            NP
       1.0000        0.5066        0.1289        0.2597       -0.4144  C_PM
                     1.0000       -0.4193        0.6904       -0.9326  CPBM
                                   1.0000       -0.0789        0.6410  In_RelD
                                                 1.0000       -0.4862  CP_PM
                                                               1.0000  NP

           SP         CP_RS
      -0.4810        0.3032  C_PM
      -0.9727        0.7831  CPBM
       0.5504       -0.4942  In_RelD
      -0.5941        0.6058  CP_PM
       0.9839       -0.7983  NP
       1.0000       -0.7815  SP
                     1.0000  CP_RS
```

Source: Gretl SW

As was already mentioned, the only modification of variables had been applied to the first function by relative differences. Therefore, the whole dataset that is going to be used for the multi-equational model are shown in the *Table 8* below.

Table 8: Data set of multi-equations model

Year	UV	C PM [kg/y/capita]	CP BM [CZK/kg]	In_RelD *[thousand CZK]*	TV	CP_PM *[CZK/kg]*	NP *[thousand heads]*	SP *[thousand heads]*	CP_RS *[CZK/kg]*
2000	1	40,90	114,205	-	1	97,635	3687,967	4513,596	6,099
2001	1	40,90	106,785	1,087677	2	103,07	3593,717	4286,6	6,904
2002	1	40,90	107,195	1,079705	3	81,195	3440,925	4407	6,467
2003	1	41,50	107,025	1,058361	4	84,97	3362,801	4414	7,348
2004	1	41,10	114,080	1,063055	5	90,935	3126,539	4085	7,183
2005	1	41,50	119,065	1,050269	6	84,645	2876,834	3760	5,628
2006	1	40,70	122,785	1,065526	7	84,655	2840,375	3721	6,657
2007	1	42,00	124,275	1,072189	8	82,785	2830,415	3769	7,418
2008	1	41,31	129,315	1,078017	9	87,27	2432,984	3508	9,785
2009	1	40,90	132,135	1,033286	10	84,89	1971,417	3161	7,104
2010	1	41,59	130,465	1,022276	11	81,015	1909,232	3034	7,737
2011	1	42,07	138,380	1,024765	12	87,775	1749,092	2904	11,207
2012	1	41,29	154,670	1,025026	13	99,18	1578,827	2656	11,843
2013	1	40,33	157,285	0,998723	14	102,505	1586,627	2591	10,949
2014	1	40,72	156,335	1,029279	15	97,665	1617,061	2640,128	9,724
2015	1	42,90	155,615	1,031939	16	93,57	1559,648	2508,272	9,86
2016	1	42,84	161,765	1,044113	17	103,245	1609,945	2427,517	10,128
2017	1	42,34	168,160	1,067497	18	106,7	1490,775	2337,79	10,573
2018	1	43,18	173,125	1,075241	19	102,815	1557,218	2309,685	9,284

Source: The Czech Statistical Office, own elaboration

4.3.4 Model identification

At this point we need to identify both equations. The model identification is proceeded separately for each equation. The model is composed of two equations. The type of the mode can be determined from the matrix Beta (β) in chapter 4.3.7., accordingly to zero and non-zero values under and above the main diagonal. In case there are only zero values around the main diagonal, we would have a simple model. If there were zero values only above or under the main diagonal, it would be a recursive model that expresses a one-way relationship and in case of non-zero values around the main diagonal, the simultaneous model would be recognized. This is a model of mutual (two-way) relationship. Originally, the plan was modelling of simultaneous model, however, given the development of previous analysis and resulting selection of variables, this model should be a recursive one.

The criteria for model identification is $\boldsymbol{k}^{**} \geq \boldsymbol{g}_{\triangle} - \mathbf{1}$, where **k**** is number of variables missing in the identified equation but used in other equations; and $\boldsymbol{g}_{\triangle}$ is the number of endogenous variables used in the equation.

Table 9: Model identification

	k^{**}	g_{Δ}	$k^{**} \geq g_{\Delta} - 1$
1st equation	x5t, x6t, x7t	y1t	3 > 0
2nd equation	x1t, x2t, x3t, x4t	y2t, y1t	4 > 1

Source: Excel; Own calculation

It is apparent from *table 9* above that both of our equations are over-identified. Therefore, the model is solvable by TSLSM.

4.3.5 Parameters' estimation using TSLSM in SW Gretl

The parameters for both equations were estimated by using Two-stage least squared method (TSLSM) in Gretl software since both of them are over-identified. This method is suitable for models with more equations. Parameters of each equation must be estimated individually (equation-by-equation).

Parameters of the 1st equation:

$$y_{1t} = 20.029 - 0.091\, x_{2t} + 27.083\, x_{3t} + 0.524\, x_{4t} + \varepsilon_{1t}$$

Picture 16: Parameters estimation of the 1st equation

```
Model 1: TSLS, using observations 2001-2018 (T = 18)
Dependent variable: C_PM
Instrumented: CPBM In_RelD time
Instruments: const CP_PM NP SP CP_RS

             coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------
  const       20.0292       9.85301      2.033    0.0615   *
  CPBM        -0.0908948    0.0567337   -1.602    0.1314
  In_RelD     27.0826       9.71852      2.787    0.0146   **
  time         0.523577     0.245280     2.135    0.0510   *
```

Source: Gretl SW

Parameters of the 2nd equation:

$$y_{2t} = 219.431 - 2.822\, y_{1t} + 0.0479\, x_{5t} - 0.0483\, x_{6t} + 4.316\, x_{7t} + \varepsilon_{2t}$$

Picture 17: Parameters' estimation of 2nd equation

```
Model 2: TSLS, using observations 2001-2018 (T = 18)
Dependent variable: CP_PM
Instrumented: NP SP CP_RS
Instruments: const C_PM CPBM In_RelD time

             coefficient   std. error    t-ratio   p-value
  ---------------------------------------------------------
  const       219.431      131.123        1.673    0.1181
  C_PM         -2.82220      2.00740     -1.406    0.1832
  NP            0.0479984    0.0125068    3.838    0.0021   ***
  SP           -0.0482982    0.0176337   -2.739    0.0169   **
  CP_RS         4.31549      3.21897      1.341    0.2030
```

Source: Gretl SW

4.3.6 Model verification

Statistical verification

Statistical verification was done for each equation individually in software Gretl. Based on the outputs from this program, we can determine the significance of parameters and overall quality of these models.

In the first equation, there are three statistically significant parameters out of four at a significance level α = 0.05. Even though the highest level of statistical significance 0.1 (***) had not been reached by any of the variables, the *Income* adjusted by relative difference is of statistical significance level 0.5 (**) and the *constant* with *time vector* has the level of statistical significance 0.1 (*). *Consumer price of beef* was not confirmed as a statistically significant variable in this model.

The adjusted R – squared $\overline{R^2}$ of the first equation is equal to 0.559. In the same *picture 18*, there is a value of $R^2 = 0.63$, meaning that the quality of our first model CPM is explained by exogenous variables at least more than 60%, 63.7% to be exact. Also, the p-value confirms the significance of the whole model, as it is lower than alpha level (0.0084 < 0.01). Thus, this model is also good statistically (significant).

Generally, the quality of both models might be lowered, due to omitting some important factor, which then has an influence on the model as a whole or by event that had affected the otherwise functioning economic lows and stereotypes. Therefore, it is not suggestible.

Picture 18: Statistical significance of the parameters from the first equation

```
Model 1: TSLS, using observations 2001-2018 (T = 18)
Dependent variable: C_PM
Instrumented: CPBM In_RelD time
Instruments: const CP_PM NP SP CP_RS

             coefficient   std. error   t-ratio   p-value
  --------------------------------------------------------
  const      20.0292       9.85301       2.033    0.0615   *
  CPBM       -0.0908948    0.0567337    -1.602    0.1314
  In_RelD    27.0826       9.71852       2.787    0.0146   **
  time        0.523577     0.245280      2.135    0.0510   *

Mean dependent var    41.55944   S.D. dependent var   0.831034
Sum squared resid     4.906769   S.E. of regression   0.592016
R-squared             0.637241   Adjusted R-squared   0.559507
F(3, 14)              5.837463   P-value(F)           0.008385
rho                  -0.073956   Durbin-Watson        2.139140
```

Source: Gretl SW

Quality of the second model is higher compared to the first one. There are 83.33% of the variables explained by the model with the $R^2 = 0.8333$ (see *Picture 19*). The value of adjusted R^2 in the second equation is 0,7820 expressing explanation of endogenous variable by exogenous variables by 78.20% with respect to relevance of the selected variables. P-value with value of 0.008, being lower than alpha level proves the quality of the model.

Regarding statistical significances of estimated parameters, two out of five had been validated at a significance level $\alpha = 0.05$, in the second equation. The highest level of statistical significance 0.1 (***) had been reached by *Number of pigs*, followed by *Slaughtered pigs* with statistical significance level 0.5 (**). None of the other variables has the level of statistical significance 0.1 (*) meaning that *Consumption of pork* and *Consumer price of rape seed* were not confirmed as a statistically significant variables in this model.

Picture 19: Statistical significance of the parameters from the second equation

```
Model 2: TSLS, using observations 2001-2018 (T = 18)
Dependent variable: CP_PM
Instrumented: NP SP CP_RS
Instruments: const C_PM CPBM In_RelD time

             coefficient    std. error    t-ratio   p-value
  --------------------------------------------------------
  const      219.431        131.123        1.673    0.1181
  C_PM        -2.82220        2.00740     -1.406    0.1832
  NP           0.0479984      0.0125068    3.838    0.0021   ***
  SP          -0.0482982      0.0176337   -2.739    0.0169   **
  CP_RS        4.31549        3.21897      1.341    0.2030

Mean dependent var   92.16028   S.D. dependent var   8.910541
Sum squared resid    231.5371   S.E. of regression   4.220254
R-squared            0.833312   Adjusted R-squared   0.782023
F(4, 13)             13.90700   P-value(F)           0.000126
Log-likelihood      -301.3900   Akaike criterion     612.7800
Schwarz criterion    617.2319   Hannan-Quinn         613.3939
rho                  0.028554   Durbin-Watson        1.863889
```

Source: Gretl SW

<u>Economic verification</u>

Economic verification of ***the 1st equation***:

- + 20.029 is the value of an intercept, C PM in kg/year/capita ⇒ Positive relationship was proven by economic verification, that is in accordance with the theory. It is a constant and shows the consumption of pork meat adjusted from all other factors, meaning, if the other factors were equal to 0, the Consumption of Pork meat would be still equal to 20.029 kg/yr/capita. Therefore, as consumption should be positive, and our is positive, it satisfies the presumption… ✓
- - 0.091 = CP BM ⇒ if the CP BM ↑ by 1 unit ⇒ C PM ↓ by 0.091 kg/year/capita ⇒ according to economic theory it was assumed that if CP BM ↑ ⇒ C PM ↑ as it is a consumer price of the substitutional good…this might be caused by unpredictable events that happened within the selected time period and influenced economic laws that are under the normal circumstances working. Or simply by other factors such as age, education, tradition, place of living or religion. Nevertheless, the parameter has not that big influence on the dependent variable. ✗
- + 27.083 = In ⇒ if the income ↑ by 1 unit ⇒ C PM ↑ by 27.083 kg/year/capita ⇒ based on the economic theory this relationship should be positive (In ↑ ⇒ C CP ↑), until it reaches the level of saturation and therefore, this verification goes along with our presumption ✓

- +0.524 = TV (time trend or time vector) ⇒ C PM ↑ by 0.524 kg/year/capita

  ⇒ the consumer price of pork is growing up by roughly CZK 0.524 every year and thus, this assumption was satisfied ✓

Economic verification of ***the 2nd equation***:

- + 219.431 = intercept, CP PM in CZK/kg ⇒ Positive relationship

  ⇒ constant, it shows the consumer price of pork meat adjusted from other factors. If the other factors were equal to zero, the CP pork would be 219.431 CZK/kg) ⇒ consumer price should be positive as the negative one would not make any sense and ours is a thus, it is correct according to economic theory… ✓

- - 2.822 = C PM ⇒ if C PM ↑ by 1 unit ⇒ CP C ↓ by 2.822 CZK/kg

  ⇒ according to the economic theory it was assumed that if C PM ↑⇒ CP C ↓ as this is a direct price relationship, it should be a negative one. With growing consumption, the supply side is satisfied, and they want to keep the consumption. Therefore, they will lower the price of the good to attract more consumers until the level of saturation is reached. ✓

- + 0.048 = N P ⇒ if N P ↑ by 1 unit ⇒ CP PM ↑ by 0.048 CZK/kg

  ⇒ the number of pigs on the Czech Republic territory was selected as it represents the supply and therefore, it has an impact on the price of processed meat. They should have negative relationship – as the number of pigs is growing, the price is decreasing (sellers want to sell all the supplies or inventories to the consumers). The relation N P ↑ ⇒ CP PM ↓ was not proven in this equation… ✗

- - 0.0483 = S P ⇒ if S P ↑ by 1 unit ⇒ CP PM ↓ by 0.0483 CZK/kg ✓

  ⇒ slaughtered pigs were assumed to have a negative relationship with the consumer price of pork as well; if S P ↑ ⇒ CP PM ↑ as there are more animals on the market to process and sell and thus, the more is produced, the more is consumed…this presumption was verified…

- + 4.316 = CP RS ⇒ if CP RS ↑ by 1 unit ⇒ CP PM ↑ by 4.316 CZK/kg

  ⇒ based on economic theory this relationship should be positive, as rape seed is one of major ingredient of pigs feeding and therefore, as an input, it affects the price of the final product ; C IC ↑ ⇒ CP C ↓ …this verification is in accordance with our assumption ✓

Overall, only two of our original assumptions were not proven as correct after the economic verification. Meaning that from an economic point of view, the quality of the model is very good.

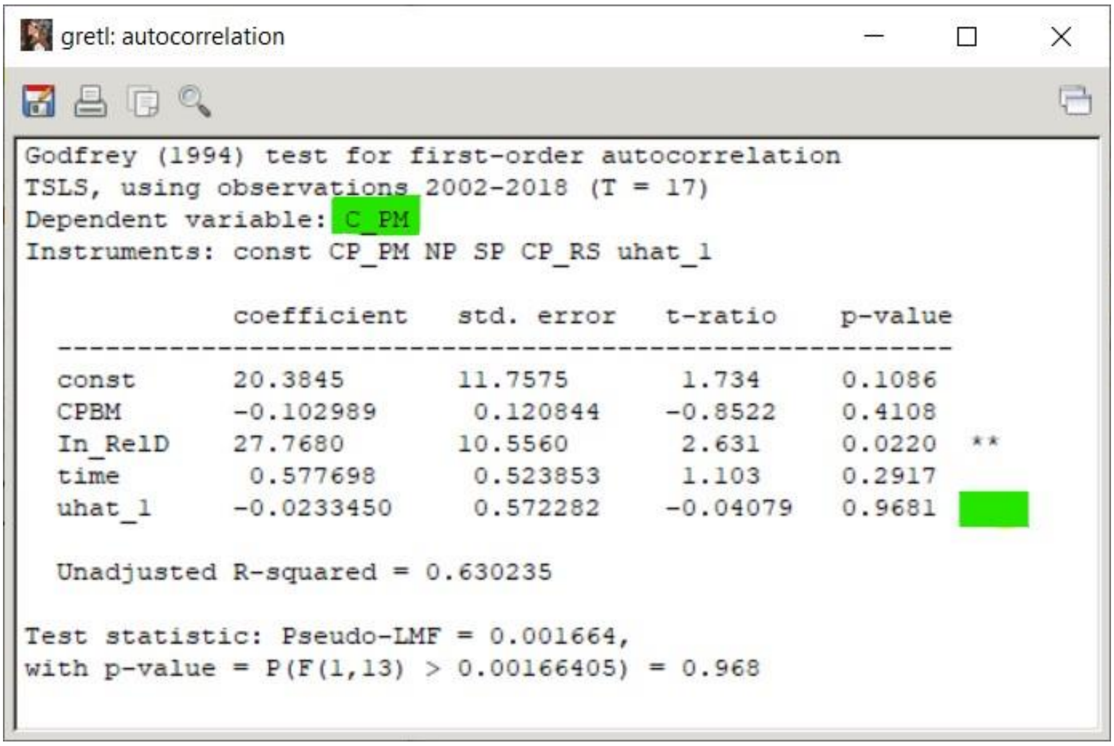
Econometric verification

Autocorrelation

$$H_0\!: \ \rho = 0 \ \Rightarrow \textit{There is } \boldsymbol{NO} \textit{ autocorrelation in the model}$$
$$H_A\!: \rho \neq 0 \ \Rightarrow \textit{There } \boldsymbol{IS} \textit{ an autocorrelation in the model}$$

In ***the 1st equation*** we can observe p-value = 0.968 (*picture 20*), which is greater than alpha level and thus the null hypothesis cannot be rejected as there is no autocorrelation present.

Picture 20: Autocorrelation of the 1st equation in Multiple - equations model



gretl: autocorrelation

```
Godfrey (1994) test for first-order autocorrelation
TSLS, using observations 2002-2018 (T = 17)
Dependent variable: C_PM
Instruments: const CP_PM NP SP CP_RS uhat_1

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const       20.3845      11.7575       1.734     0.1086
  CPBM        -0.102989     0.120844    -0.8522    0.4108
  ln_RelD     27.7680      10.5560       2.631     0.0220   **
  time         0.577698     0.523853     1.103     0.2917
  uhat_1      -0.0233450    0.572282    -0.04079   0.9681

  Unadjusted R-squared = 0.630235

Test statistic: Pseudo-LMF = 0.001664,
with p-value = P(F(1,13) > 0.00166405) = 0.968
```

Source: Gretl SW

P-value of ***the 2nd equation*** is also higher than alpha level, so the null hypothesis is accepted and that expresses no autocorrelation occurring in this case either (*Picture 21*).

Picture 21: Autocorrelation of the 2nd equation in Multiple - equations model

```
Godfrey (1994) test for first-order autocorrelation
TSLS, using observations 2002-2018 (T = 17)
Dependent variable: CP_PM
Instruments: const C_PM CPBM In_RelD time uhat_1

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const      217.604       106.659       2.040     0.0661   *
  C_PM        -2.59916       1.63807    -1.587     0.1409
  NP           0.0431255     0.0123913   3.480     0.0051   ***
  SP          -0.0454739     0.0155837  -2.918     0.0140   **
  CP_RS        3.63865       3.73700     0.9737    0.3511
  uhat_1      -0.0300610     0.615900   -0.04881   0.9619

  Unadjusted R-squared = 0.860989

Test statistic: Pseudo-LMF = 0.002382,
with p-value = P(F(1,12) > 0.00238225) = 0.962
```

Source: Gretl SW

Heteroscedasticity

*H_0: There is **NO** heteroscedasticity in the model. (p- val. > α level)*

*H_A: There **IS** heteroscedasticity in the model. (p- val. < α level)*

In the Pesaran-Taylor test for heteroscedasticity, the p-value of the 1st equation is 0.514 *(picture 22)* and of the 2nd one = 0.141 *(picture 23)*. Both of them are greater than the alpha level. Therefore, the null hypothesis might be accepted with conclusion that there is no heteroscedasticity in the model, but homoscedasticity. The variance is constant and finite.

Picture 22: Heteroscedasticity of the 1st equation from the Multiple - equations model

```
Pesaran-Taylor test for heteroskedasticity
OLS, using observations 2001-2018 (T = 18)
Dependent variable: uhat^2

             coefficient    std. error   t-ratio   p-value
  ---------------------------------------------------------
  const      -1.30987       2.42704      -0.5397   0.5968
  yhat^2      0.000915136   0.00140306    0.6522   0.5235

  Unadjusted R-squared = 0.025900

Test statistic: HET_1 = |0.000915| / 0.001403 = 0.652242,
with p-value = 2 * P(z > 0.652242) = 0.514
```

Source: Gretl SW

Picture 23: Heteroscedasticity of the 2nd equation from the Multiple - equations model

```
Pesaran-Taylor test for heteroskedasticity
OLS, using observations 2001-2018 (T = 18)
Dependent variable: uhat^2

             coefficient    std. error    t-ratio   p-value
  ---------------------------------------------------------
  const      47.1300        23.5623        2.000    0.0627   *
  yhat^2     -0.00400850     0.00272053   -1.473    0.1600

  Unadjusted R-squared = 0.119475

Test statistic: HET_1 = |-0.004008| / 0.002721 = 1.473424,
with p-value = 2 * P(z > 1.473424) = 0.141
```

Source: Gretl SW

Normality test of Residuals

*H_0: There **IS** normal distribution of residuals in the model. (p-val > α level)*

*H_A: There is **NOT** normal distribution of residuals in the model. (p-val < α level)*

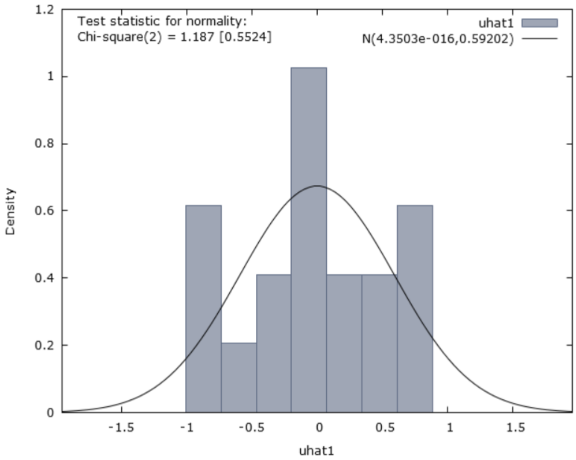
From the Normality test of residuals we can observe that the p-value of the first equation is equal to 0.55 (*picture 24*) and of the second one is 0.79 (*picture 25*). Both of them are bigger than alpha, so we can accept the null hypothesis and claim that the residuals are normally dispersed (*figure 8 and 9*).

Picture 24: Normality test of the 1st equation in Multiple - equations model

```
Frequency distribution for uhat1, obs 2-19
number of bins = 7, mean = 4.3503e-016, sd = 0.592016

       interval          midpt    frequency    rel.     cum.

           < -0.73740  -0.87285        3      16.67%   16.67% ******
  -0.73740 - -0.46649  -0.60194        1       5.56%   22.22% *
  -0.46649 - -0.19557  -0.33103        2      11.11%   33.33% ***
  -0.19557 -  0.075339 -0.060117       5      27.78%   61.11% **********
  0.075339 -  0.34625   0.21080        2      11.11%   72.22% ***
   0.34625 -  0.61716   0.48171        2      11.11%   83.33% ***
          >=  0.61716   0.75262        3      16.67%  100.00% ******

Test for null hypothesis of normal distribution:
Chi-square(2) = 1.187 with p-value 0.55236
```

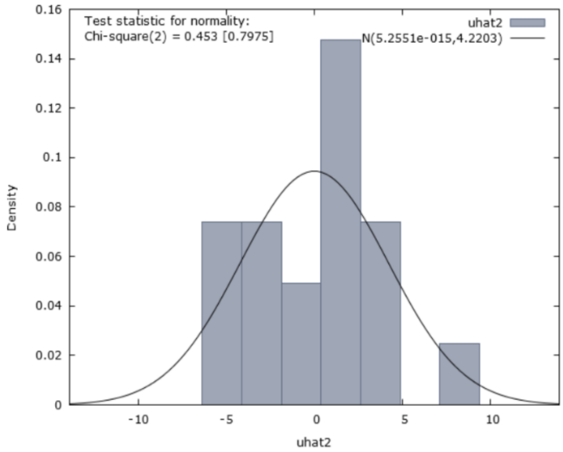
Source: Gretl SW

Figure 9: Normal distribution of residuals from the 1st equation



Source: Gretl SW

Figure 8: Normal distribution of residuals from the 2nd equation



Source: Gretl SW

Picture 25: Normality test of the 2nd equation in Multiple - equations model

```
Frequency distribution for uhat2, obs 2-19
number of bins = 7, mean = 5.25506e-015, sd = 4.22025

       interval          midpt   frequency    rel.     cum.

            < -4.1291   -5.2568        3     16.67%   16.67% ******
   -4.1291 - -1.8738   -3.0014        3     16.67%   33.33% ******
   -1.8738 -  0.38158  -0.74609       2     11.11%   44.44% ***
   0.38158 -  2.6369    1.5092        6     33.33%   77.78% ************
    2.6369 -  4.8922    3.7646        3     16.67%   94.44% ******
    4.8922 -  7.1476    6.0199        0      0.00%   94.44%
          >=  7.1476    8.2752        1      5.56%  100.00% *

Test for null hypothesis of normal distribution:
Chi-square(2) = 0.453 with p-value 0.79751
```

Source: Gretl SW

4.3.7 Matrix B, Γ and matrix M

Structural form of the model

For now, our model is structural as we use endogenous variables to express each other and exogenous variables as well. It is needed to create matrix Beta, containing dependent variables in the model and matrix Gama, including the independent variables of our model.

$$y_{1t} - \gamma_{11}x_{1t} - \gamma_{12}x_{2t} - \gamma_{13}x_{3t} - \gamma_{14}x_{4t} = \varepsilon_{1t}$$
$$y_{2t} - \beta_{21}y_{1t} - \gamma_{21}x_{1t} - \gamma_{25}x_{5t} - \gamma_{26}x_{6t} - \gamma_{27}x_{7t} = \varepsilon_{2t}$$

$$\boldsymbol{\beta} = \begin{pmatrix} \mathbf{1} & \mathbf{0} \\ -\boldsymbol{\beta}_{21} & \mathbf{1} \end{pmatrix} \qquad \boldsymbol{\gamma} = \begin{pmatrix} -\boldsymbol{\gamma}_{11} & -\boldsymbol{\gamma}_{12} & -\boldsymbol{\gamma}_{13} & -\boldsymbol{\gamma}_{14} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ -\boldsymbol{\gamma}_{21} & \mathbf{0} & -\mathbf{0} & \mathbf{0} & -\boldsymbol{\gamma}_{25} & -\boldsymbol{\gamma}_{26} & -\boldsymbol{\gamma}_{27} \end{pmatrix}$$

After replacing theoretical parameters by estimated ones, we get:

$$y_{1t} - 20.029 + 0.091x_{2t} - 27.083x_{3t} - 0.524x_{4t} = \varepsilon_{1t}$$
$$y_{2t} + 2.822y_{1t} - 219.431 - 0.048x_{5t} + 0.048x_{6t} - 4.316x_{7t} = \varepsilon_{2t}$$

$$\boldsymbol{\beta} = \begin{pmatrix} \mathbf{1} & \mathbf{0} \\ \mathbf{2.822} & \mathbf{1} \end{pmatrix}$$

$$\boldsymbol{\gamma} = \begin{pmatrix} \mathbf{-20.029} & \mathbf{0.091} & \mathbf{-27.083} & \mathbf{-0.524} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{-219.431} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{-0.048} & \mathbf{0.048} & \mathbf{-4.316} \end{pmatrix}$$

Hence, the formula will be applied to calculate the matrix of multipliers $M = -B^{-1} * \Gamma$

$$\mathbf{M} = \begin{matrix} \mathbf{20.029} & \mathbf{-0.091} & \mathbf{27.083} & \mathbf{0.524} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{162.909} & \mathbf{0.257} & \mathbf{-76.428} & \mathbf{-1.479} & \mathbf{0,048} & \mathbf{-0.048} & \mathbf{4.316} \end{matrix}$$

The matrix of multipliers enables us to create the reduced form of our recursive model.

<u>Reduced form of the model</u>

$$y_{1t} = 20.029 - 0.091x_{2t} + 27.083x_{3t} + 0.524x_{4t} + \varepsilon_{1t}$$

$$y_{2t} = 162.909 + 0.257x_{2t} - 76.428x_{3t} - 1.479x_{4t} + 0.048x_{5t} - 0.048x_{6t} + 4.316x_{7t} + \varepsilon_{2t}$$

In reduced model we can observe the complex influence of all exogenous variables on endogenous variables.

<u>Differences between structural and reduced form</u>

Parameters of the structural form of a model represent the direct influences of both predeterminant and other explanatory variables on endogenous variable. Its matrix form is $B_{yt} + \Gamma_{xt} = u_t$.

Parameters of the reduced form represent the comprehensive - direct and indirect (mediated) effects of predetermined variables on endogenous variable. The reduced form is also appropriate for the prognosis.

In the first equation parameters of variables $\mathbf{x_1}$**,** $\mathbf{x_2}$**,** $\mathbf{x_3}$**,** $\mathbf{x_4}$**,** represent complex effect on explained variable $\mathbf{y_{1t}}$. The linkages are direct. There is no parameter of variable expressing vicarious effect because there were not included in the structural form.

In the second equation parameters of variables $\mathbf{x_1}$, $\mathbf{x_3}$, $\mathbf{x_4}$, $\mathbf{x_5}$, $\mathbf{x_6}$, $\mathbf{x_7}$ represent complex effect on explained variable $\mathbf{y_{2t}}$. The linkages are direct and mediated through the predeterminant variable

$\mathbf{y_{1t}}$. Parameters of variables $\mathbf{x_2}$, $\mathbf{x_3}$ and $\mathbf{x_4}$ express vicarious effect because these are not included in the structural form.

4.3.8 Model application

Coefficients of elasticity

To find out the effect of explaining variables on the explained variable the elasticity is calculated. Elasticity represents the amount in % of how much the explained variable changes in case of change in on the explaining variables. If there is a zero-value present as an elasticity, it means there is no relationship between these two variables.

The intensity of the effect of exogenous on endogenous variables is expressed, as elasticity, in the *table 10* below. This allows us to compare each exogenous variable. Calculation was done for year 2018.

Table 10: Coefficients of elasticity

	1st equation	2nd equation
x2 (CP BM)	-0,363411123	0,439991765
x3 (In)	0,671737698	-0,813291165
x4 (TV)	0,229658183	-0,278053431
x5 (NP)	0	0,73973644
x6 (SP)	0	-1,097186238
x7 (CP RS)	0	0,396554542

Source: Excel; Own Calculations

Example:

If the consumer price of beef increases by 1%, the consumption of pork meat decreases by 0.36%.

If the consumer price of beef increases by 1%, the consumer price of pork increases by 0.44%.

Scenarios' simulation

How would the income be influenced, if the consumption of pork increases by 20%?

It would increase by 13.44%.

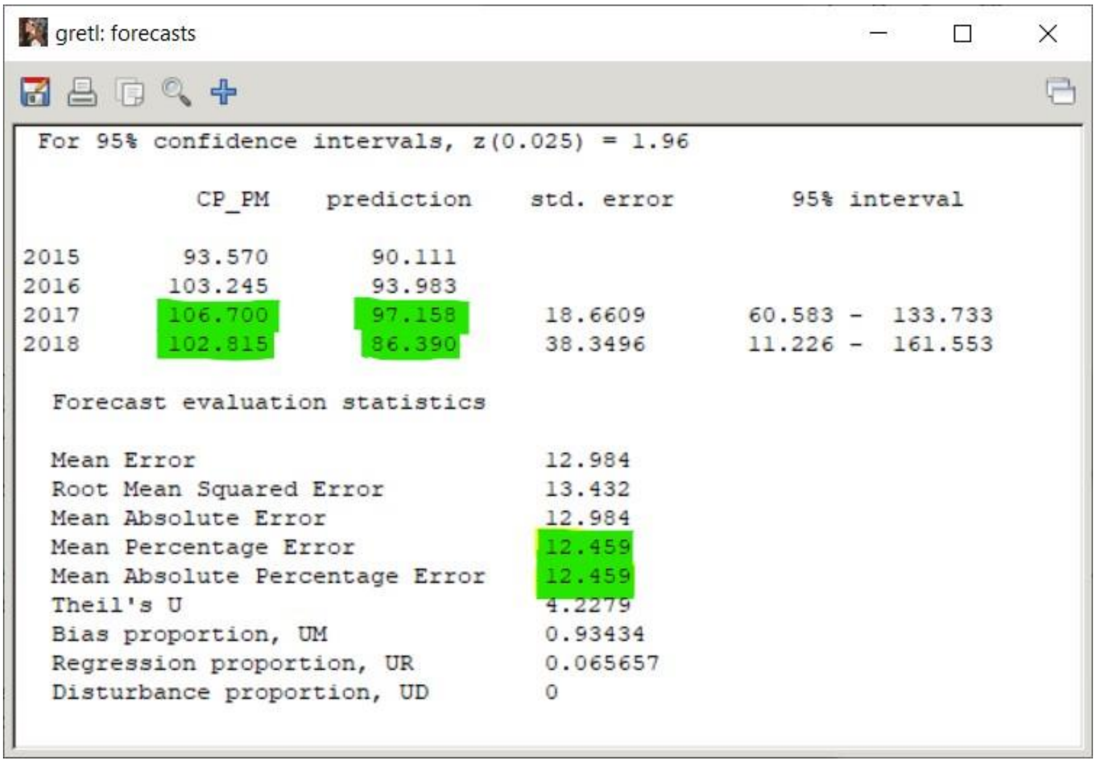
How should the consumer price of beef change, so that consumption of pork in 2018 would be 45.7 kg/yr/capita?

It would mean an increase of 5.51% (from 43.18 kg/yr/capita) in consumption of pork meat and thus, 2.0024% decrease in consumer price of beef.

Ex-post prognosis

Let´s reduce out set range of the last two years 2017 and 2018. For the calculation of prognosis, the Gretl software is used. The output is following *Picture 26* showing both, the point and 95% interval prediction for pork meat consumer price for years 2017 and 2018.

Picture 26: Ex-post prognosis of Pork meat consumer price for years 2017 and 2018



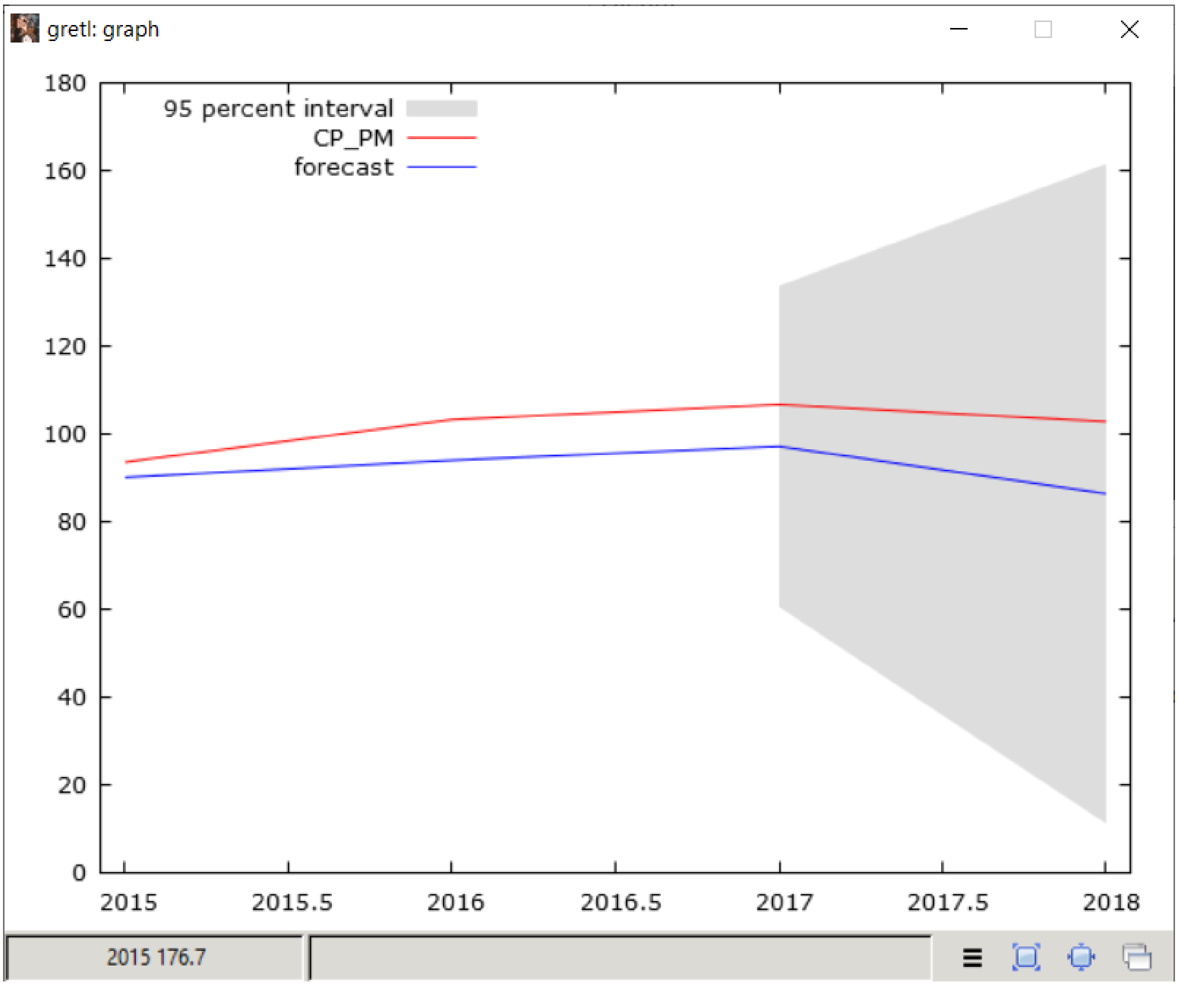
```
gretl: forecasts

For 95% confidence intervals, z(0.025) = 1.96

              CP_PM    prediction    std. error        95% interval

2015         93.570       90.111
2016        103.245       93.983
2017        106.700       97.158      18.6609       60.583 -   133.733
2018        102.815       86.390      38.3496       11.226 -   161.553

  Forecast evaluation statistics

  Mean Error                          12.984
  Root Mean Squared Error             13.432
  Mean Absolute Error                 12.984
  Mean Percentage Error               12.459
  Mean Absolute Percentage Error      12.459
  Theil's U                           4.2279
  Bias proportion, UM                 0.93434
  Regression proportion, UR           0.065657
  Disturbance proportion, UD          0
```

Source: Gretl SW

As we utilized a linear function for our model this time, it is not necessary to de-linearize the estimated value of Consumer price of pork meat that was forecasted. The simple comparison of predicted values with actual values is possible.

From the *Picture 26* is visible that the average price for pork meat per kilogram in year 2017 was CZK 106.7 next to the prognosis that predicts CZK 97.2. The same interpretation applies for 2018. Therefore, we can claim, the prognosis is pretty accurate as the numbers are almost identical. Relative to our observations, our estimates are +12.459 away, which is the deviation and it means, our estimates are equivalent to 112.459% of the real observation (Mean percentage error in the *picture 26*). We can also observe, that overall, the forecast should be on average only 12.45% away from the actual observation that is represented by Mean absolute percentage error in the *picture 26*. The results are demonstrated in *figure 10*, where we can observe that the red line (real prices of pork meat are within the 95% confidence interval). Therefore, the model is recommendable for further predictions.

Figure 10: Graphical illustration of ex-post prognosis of CP PM for 2017 and 2018



Source: Gretl SW

4.4 One equation model

Considering the estimation of multiple equations model had not proven nor simultaneous nor recursive relationship between functions of Consumption of Pork and Consumer price of Pork, it was decided to model a solo one equation model for Consumer price of Pork. In case of one-equation model there are formulated assumptions based on economic theory and afterwards, the economic and econometric model are constructed. Data set is presented and the parameters are estimated using Ordinary Least Square Method (OLSM) in software GRETL, followed by economic, statistic and econometric verification. As a last step an application of the model is done. For some of the side calculations MS Excel is going to be used.

4.4.1 Economic model

Assumptions

The aim of this chapter is to analyse, verify and express econometric model for *Consumer price of Pork Meat in the Czech Republic*. Therefore, the dependent variable of the model is Consumer price of pork meat, developing in the territory of the Czech Republic. Based on economic theory, the independent variables were chosen. The model is going to be composed of Consumption of pork meat (in the Czech Republic), Number of pigs the market dispone with, the number of pigs, that were slaughtered for further meat processing purposes (Slaughtered pigs) and Consumer price of Rape Seed as the main input to feeding of pigs in the Czech Republic as the last explanatory variable.

The first assumption would be the influence of consumption of pork meat. If the consumption of this commodity increase, we assume that the Consumer price of pork meat will decrease as the producers will be satisfied with sales until there is still what to sell and they need to attract the consumer and stimulate their need for this product. Consumers are still limited with their budget and the preference of other substitutional good is a thread to the suppliers.

$$\uparrow \boldsymbol{C\ PM} \Rightarrow \downarrow \boldsymbol{CP\ PM}$$

Another chosen variable is a Number of pigs on the Czech market. As long as the producers of pork meat have enough of the input, they can produce the final product for consumers. If there was a scarcity of the input, it would directly affect the price of the commodity and therefore, it is expected that if the number of pigs is growing, the consumer price is decreasing.

$$\uparrow \boldsymbol{N\ P} \Rightarrow \downarrow \boldsymbol{CP\ PM}$$

Similarly, it is with number of pigs, that were slaughtered (slaughtered pigs). The number of pigs the Czech market dispone with itself, does not say much. There might be loses during the pigs' life cycle. Also, the population of pigs is highly susceptible to the illnesses and there are epidemies time to time when there must be even the whole breeding disposed. So, within the time from the birth and slaughterhouse a lot can happen and thus, only the final number of slaughtered animals determines the quantity of the input for the agricultural produces that has an impact on the price of the product. If the number of slaughtered pigs is increased, it is expected the price of pork meat is going to decrease.

$$\uparrow \boldsymbol{S\ P} \Rightarrow \downarrow \boldsymbol{CP\ PM}$$

Finally, one of the main variables that affect the cost of the pig that is bread for meat purposes is a food. Feeding represents one of the biggest item on the cost spectrum of pigs breeding. In the Czech Republic the rape seed creates a significant share of the structure of feeding mixtures for livestock, or particularly the pigs. Based on this presumption is that if the price of rape seed increases, the consumer price of the final product – the pork meat – increases as well.

$$\uparrow \boldsymbol{CP\ RS}\ \Rightarrow \uparrow \boldsymbol{CP\ PM}$$

Given these, the economic model can be constructed.

Economic model

$$\boldsymbol{y_{1t} = f(x_{1t}, x_{2t}, x_{3t}, x_{4t})}$$

Where:

- $\boldsymbol{y_{1t}}$ is Consumer price of Pork Meat (CP PM)
- $\boldsymbol{x_{1t}}$ stands for Consumption of Pork Meat (C PM)
- $\boldsymbol{x_{2t}}$ expresses Number of Pigs (NP)
- $\boldsymbol{x_{3t}}$ represents Slaughtered Pigs (SP)
- $\boldsymbol{x_{4t}}$ is Consumer price of Rape Seed (CP RS)

Therefore, in our case it would look like the following function:

$$\boldsymbol{CP\ PM = f(C\ PM, NP, SP, CP\ RS)}$$

4.4.2 Econometric model

Standard econometric model is represented by an equation in linear form:

$$\boldsymbol{y_{1t} = \gamma_{11}x_{1t} + \gamma_{12}x_{2t} + \gamma_{13}x_{3t} + \gamma_{14}x_{4t} + \gamma_{15}x_{5t} + \varepsilon_{1t}}$$

Declaration of variables and units

Where:

- $\boldsymbol{y_{1t}}$ is Consumer price of Pork Meat (CP PM)…CZK/kg
- $\boldsymbol{x_{1t}}$ = Unit vector (UV) = u_{1t}= Intercept
- $\boldsymbol{x_{2t}}$ stands for Consumption of Pork Meat (C PM)…kg/year/capita
- $\boldsymbol{x_{3t}}$ expresses Number of Pigs (NP)…thousands of heads
- $\boldsymbol{x_{4t}}$ represents Slaughtered Pigs (SP)…thousands of heads
- $\boldsymbol{x_{5t}}$ is Consumer price of Rape Seed (CP RS)…CZK/kg

- ε_{1t} = Error Term (Residuals)

4.4.3 Data

Data Table

Data in *table 11* are secondary data that were collected from The Czech Statistical Office. The model is based on annual data, which represent time series with 18 observations from year 2000 until 2018.

Table 11: Data set of CP PM model

Year	CP_PM *[CZK/kg]*	UV	C PM [kg/y/capita]	NP *[thousand heads]*	SP *[thousand heads]*	CP_RS *[CZK/kg]*
2000	97,635	1	40,90	3687,967	4513,596	6,099
2001	103,07	1	40,90	3593,717	4286,6	6,904
2002	81,195	1	40,90	3440,925	4407	6,467
2003	84,97	1	41,50	3362,801	4414	7,348
2004	90,935	1	41,10	3126,539	4085	7,183
2005	84,645	1	41,50	2876,834	3760	5,628
2006	84,655	1	40,70	2840,375	3721	6,657
2007	82,785	1	42,00	2830,415	3769	7,418
2008	87,27	1	41,31	2432,984	3508	9,785
2009	84,89	1	40,90	1971,417	3161	7,104
2010	81,015	1	41,59	1909,232	3034	7,737
2011	87,775	1	42,07	1749,092	2904	11,207
2012	99,18	1	41,29	1578,827	2656	11,843
2013	102,505	1	40,33	1586,627	2591	10,949
2014	97,665	1	40,72	1617,061	2640,128	9,724
2015	93,57	1	42,90	1559,648	2508,272	9,86
2016	103,245	1	42,84	1609,945	2427,517	10,128
2017	106,7	1	42,34	1490,775	2337,79	10,573
2018	102,815	1	43,18	1557,218	2309,685	9,284

Source: The Czech Statistical Office; own elaboration

Summary statistics

The table below includes descriptive data such as mean, median, minimal, maximal value and standard deviation of all variables included in the multi-equations model to provide statistics summary.

Table 12: Summary Statistics

	y_{1t}	x_{1t}	x_{2t}	x_{3t}	x_{4t}	x_{5t}
Mean	92.45	1	41.52	2359.07	3317.56	8.52
Median	90.94	1	41.31	1971.42	3161.00	7.74
Minimum	81.02	1	40.33	1490.78	2309.69	6.63
Maximum	106.70	1	43.18	3687.97	4513.60	11.84
Standard deviation	8.52	0	0.80	790.15	763.28	1.89

Source: The Czech Statistical Office, own calculations and elaboration

The interpretation of the values is to be found in chapter *4.3.3. Data*.

Correlation matrix and Multicollinearity elimination

There is a multicollinearity present between exogenous variables *Number of pigs, Slaughtered pigs* and *Consumer price of Rape Seed* (see *Picture 27*). However, considered the quality of the model, it was decided not to eliminate the multicollinearity between these three independent variables even though that might lead to increase in inaccuracy as insignificancy of the parameters for example, but it is not a wrong procedure.

Picture 27: Correlation matrix

```
Correlation Coefficients, using the observations 2000 - 2018
5% critical value (two-tailed) = 0.4555 for n = 19

         CP_PM          C_PM            NP            SP         CP_RS
        1.0000        0.2262       -0.3848       -0.4933        0.5282  CP_PM
                      1.0000       -0.4469       -0.5074        0.3397  C_PM
                                    1.0000        0.9859       -0.8184  NP
                                                  1.0000       -0.8039  SP
                                                                1.0000  CP_RS
```

Source: Gretl SW

As the multicollinearity between explanatory variables had not been removed, the dataset remains unchanged for the following steps.

4.4.4 Parameters' Estimation (using OLSM in Gretl SW)

Parameters were processed and estimated in software Gretl. The significance level for econometric modelling was determined as $\alpha = 0.05$. The relationship between selected variables was examined using Ordinary least square method. The results of the parameter estimation of the model are shown in the *Picture 28* below. These estimated parameters were inserted to the equation and by that, the general form of our econometric model was finalized:

$$y_{1t} = 265.796 - 3.391x_{2t} + 0.052x_{3t} - 0.055x_{4t} + 2.989x_{5t} + \varepsilon_{1t}$$

Picture 28: Estimation of Parameters

Model 1: OLS, using observations 2000-2018 (T = 19)
Dependent variable: CP_PM

	coefficient	std. error	t-ratio	p-value	
const	265.796	68.3572	3.888	0.0016	***
C_PM	-3.39078	1.46824	-2.309	0.0367	**
NP	0.0521362	0.00784719	6.644	1.11e-05	***
SP	-0.0545632	0.00821067	-6.645	1.10e-05	***
CP_RS	2.98997	0.865984	3.453	0.0039	***

Source: Gretl SW

4.4.5 Model verification

Model of Consumer price of the Pork Meat must be verified by Statistical, Economic and Econometric verification before it is utilized for further application.

<u>Statistical verification</u>

Statistical verification was done in software Gretl. Based on the outputs from this program, we can determine the significance of parameters and overall quality of the model. The results are presented in *Picture 29* below.

In the model of Consumer price of the Pork Meat, there are four statistically significant parameters out of five reaching the highest level of statistical significance 0.1 (***) at a significance level $\alpha = 0.05$. Those are *the intercept*, *Number of Pigs*, *Slaughtered Pigs* and *Consumer Price of Rape Seed*. The *Consumption of Pork Meat* is of statistical significance level 0.5 (**). None of the parameters was found as statistically insignificant, which is a very good and satisfactory finding.

The adjusted R – squared $\overline{R^2}$ of the model is equal to 0.781 and that represents explanation of endogenous variable by exogenous variables by 78.1% with respect to relevance of the selected variables. The model explains the Consumer price of pork meat by 82.96% with the R^2 = 0.8296. Also, the p-value equals to 0.000028 confirms the significance of the whole model, as it is lower than alpha level 0.01. Thus, this model is statistically very good (significant).

Picture 29: Statistical significance of the parameters

```
Model 1: OLS, using observations 2000-2018 (T = 19)
Dependent variable: CP_PM

             coefficient   std. error    t-ratio   p-value
  ---------------------------------------------------------
  const      265.796       68.3572        3.888    0.0016    ***
  C_PM        -3.39078      1.46824      -2.309    0.0367    **
  NP           0.0521362    0.00784719    6.644    1.11e-05  ***
  SP          -0.0545632    0.00821067   -6.645    1.10e-05  ***
  CP_RS        2.98997      0.865984      3.453    0.0039    ***

Mean dependent var   92.44842   S.D. dependent var   8.750100
Sum squared resid    234.8432   S.E. of regression   4.095670
R-squared            0.829596   Adjusted R-squared   0.780909
F(4, 14)             17.03944   P-value(F)           0.000028
Log-likelihood      -50.84738   Akaike criterion     111.6948
Schwarz criterion    116.4170   Hannan-Quinn         112.4939
rho                  0.172805   Durbin-Watson        1.485404
```

Source: Gretl SW

Economic verification

- + 265.796 = intercept, CP PM in CZK/kg ⇒ Positive relationship

  ⇒ constant, it shows the consumer price of pork meat adjusted from other factors. If the other factors were equal to zero, the CP pork would be 265.796 CZK/kg) ⇒ consumer price should be positive as the negative one would not make any sense and ours is a thus, it is correct according to economic theory…

- - 3.391 = C PM ⇒ if C PM ↑ by 1 unit ⇒ CP C ↓ by 2.391 CZK/kg

  ⇒ according to the economic theory it was assumed that if C PM ↑⇒ CP C ↓ as this is a direct price relationship, it should be a negative one. With growing consumption, the supply side is satisfied, and they want to keep the consumption. Therefore, they will lower the price of the good to attract more consumers until the level of saturation is reached.

- + 0.052 = N P ⇒ if N P ↑ by 1 unit ⇒ CP PM ↑ by 0.052 CZK/kg

  ⇒ the number of pigs on the Czech Republic territory was selected as it represents the supply and therefore, it has an impact on the price of processed meat. They should have negative relationship – as the number of pigs is growing, the price is decreasing (sellers want to sell all the supplies or inventories to the consumers). The relation N P ↑ ⇒ CP PM ↓ was not proven in this equation…

- - 0.055 = S P ⇒ if S P ↑ by 1 unit ⇒ CP PM ↓ by 0.055 CZK/kg

⇒ slaughtered pigs were assumed to have a negative relationship with the consumer price of pork as well; if S P ↑ ⇒ CP PM ↑ as there are more animals on the market to process and sell and thus, the more is produced, the more is consumed…this presumption was verified…

- + 2.989 = CP RS ⇒ if CP RS ↑ by 1 unit ⇒ CP PM ↑ by 2.989 CZK/kg

⇒ based on economic theory this relationship should be positive, as rape seed is one of major ingredient of pigs feeding and therefore, as an input, it affects the price of the final product ; C IC ↑ ⇒ CP C ↓ …this verification is in accordance with our assumption

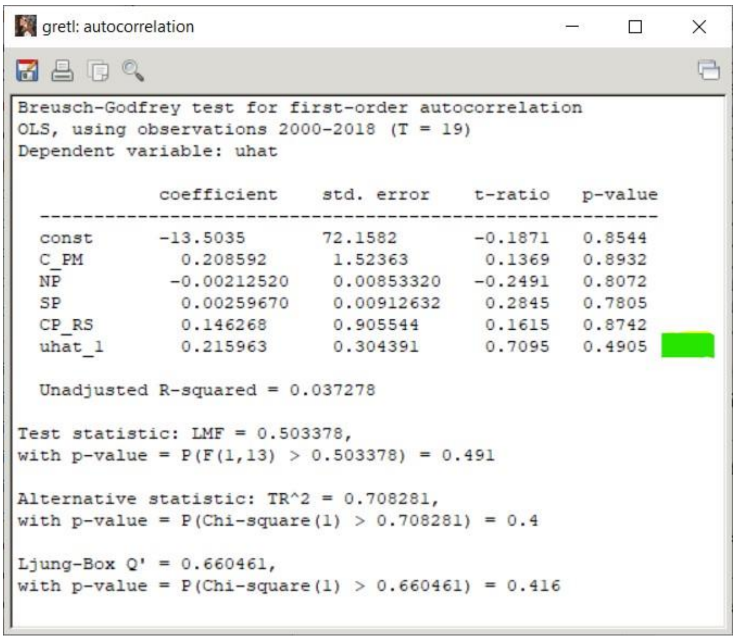
Econometric verification

Autocorrelation

$$H_0:\ \rho = 0\ \Rightarrow There\ is\ \boldsymbol{NO}\ autocorrelation\ in\ the\ model$$
$$H_A: \rho \neq 0\ \Rightarrow There\ \boldsymbol{IS}\ an\ autocorrelation\ in\ the\ model$$

The value of the Durbin-Watson DW is 1.485404 The interval is <0;4> with significance level 5% (*Picture 30*).

Picture 30: Test of Autocorrelation


gretl: autocorrelation

```
Breusch-Godfrey test for first-order autocorrelation
OLS, using observations 2000-2018 (T = 19)
Dependent variable: uhat

             coefficient    std. error    t-ratio   p-value
  ---------------------------------------------------------
  const      -13.5035       72.1582       -0.1871   0.8544
  C_PM         0.208592      1.52363       0.1369   0.8932
  NP          -0.00212520    0.00853320   -0.2491   0.8072
  SP           0.00259670    0.00912632    0.2845   0.7805
  CP_RS        0.146268      0.905544      0.1615   0.8742
  uhat_1       0.215963      0.304391      0.7095   0.4905

  Unadjusted R-squared = 0.037278

Test statistic: LMF = 0.503378,
with p-value = P(F(1,13) > 0.503378) = 0.491

Alternative statistic: TR^2 = 0.708281,
with p-value = P(Chi-square(1) > 0.708281) = 0.4

Ljung-Box Q' = 0.660461,
with p-value = P(Chi-square(1) > 0.660461) = 0.416
```

Source: Gretl SW

According to degrees of freedom the lower limit is 0.85876 and the upper one is 1.84815 for this model. Value of DW is within the interval and as verified by Gretl software, p-value = 0.491 that is is greater than alpha level, the null hypothesis is accepted with result there is no autocorrelation present in the model as visible in *Picture 30*.

Heteroscedasticity

*H_0: There is **NO** heteroscedasticity in the model. (p- val. > α level)*

*H_A: There **IS** heteroscedasticity in the model. (p- val. < α level)*

In the Breush-Pagan test for heteroscedasticity, the p-value of the model is 0.162 *(picture 31).* As this value is greater than the alpha level, the null hypothesis might be accepted with conclusion that there is no heteroscedasticity in the model, but homoscedasticity. The variance is constant and finite.

Picture 31: Heteroskedasticity

```
Breusch-Pagan test for heteroskedasticity
OLS, using observations 2000-2018 (T = 19)
Dependent variable: scaled uhat^2

             coefficient    std. error    t-ratio    p-value
  ----------------------------------------------------------
  const      23.8211        21.8275        1.091     0.2936
  C_PM       -0.449361       0.468829     -0.9585    0.3541
  NP         -0.000425054    0.00250572   -0.1696    0.8677
  SP          0.000157937    0.00262179    0.06024   0.9528
  CP_RS      -0.432194       0.276522     -1.563     0.1404

  Explained sum of squares = 13.0915

Test statistic: LM = 6.545738,
with p-value = P(Chi-square(4) > 6.545738) = 0.161931
```

Source: Gretl SW

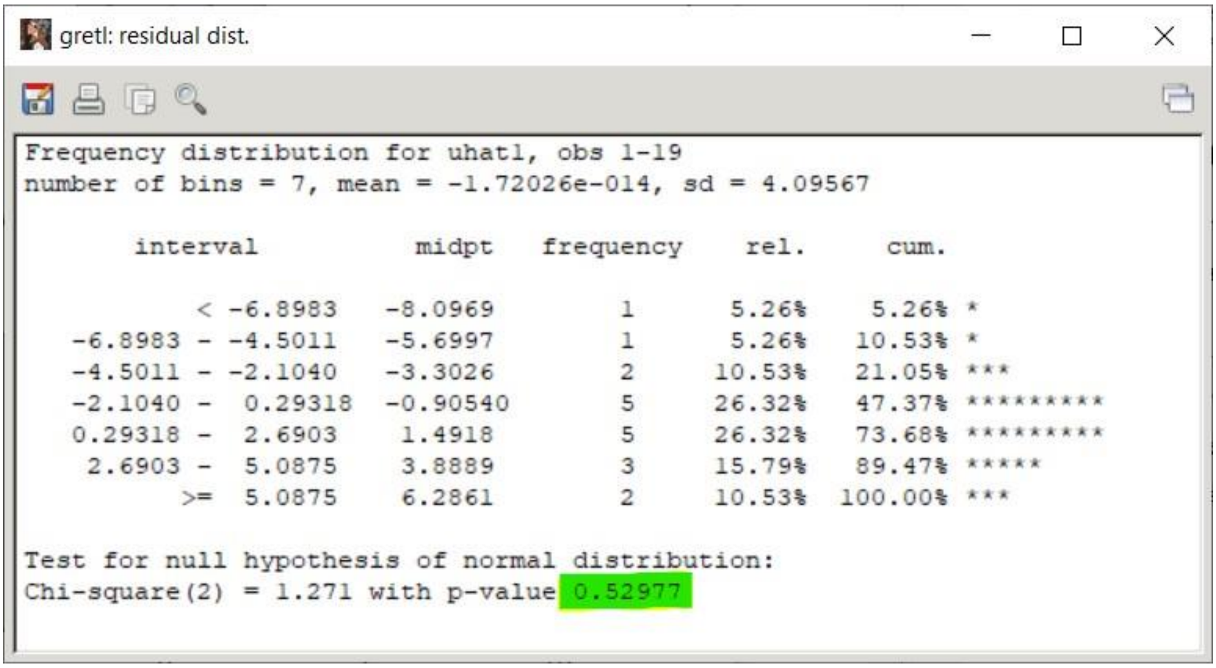
Normality test of Residuals

*H_0: There **IS** normal distribution of residuals in the model. (p-val > α level)*

*H_A: There is **NOT** normal distribution of residuals in the model. (p-val < α level)*

From the *Picture 32* of Normality test of residuals the p-value of the model is equal to 0.53 that is bigger than alpha level, so the null hypothesis can be accepted with conclusion the residuals are normally distributed (*figure 11*).

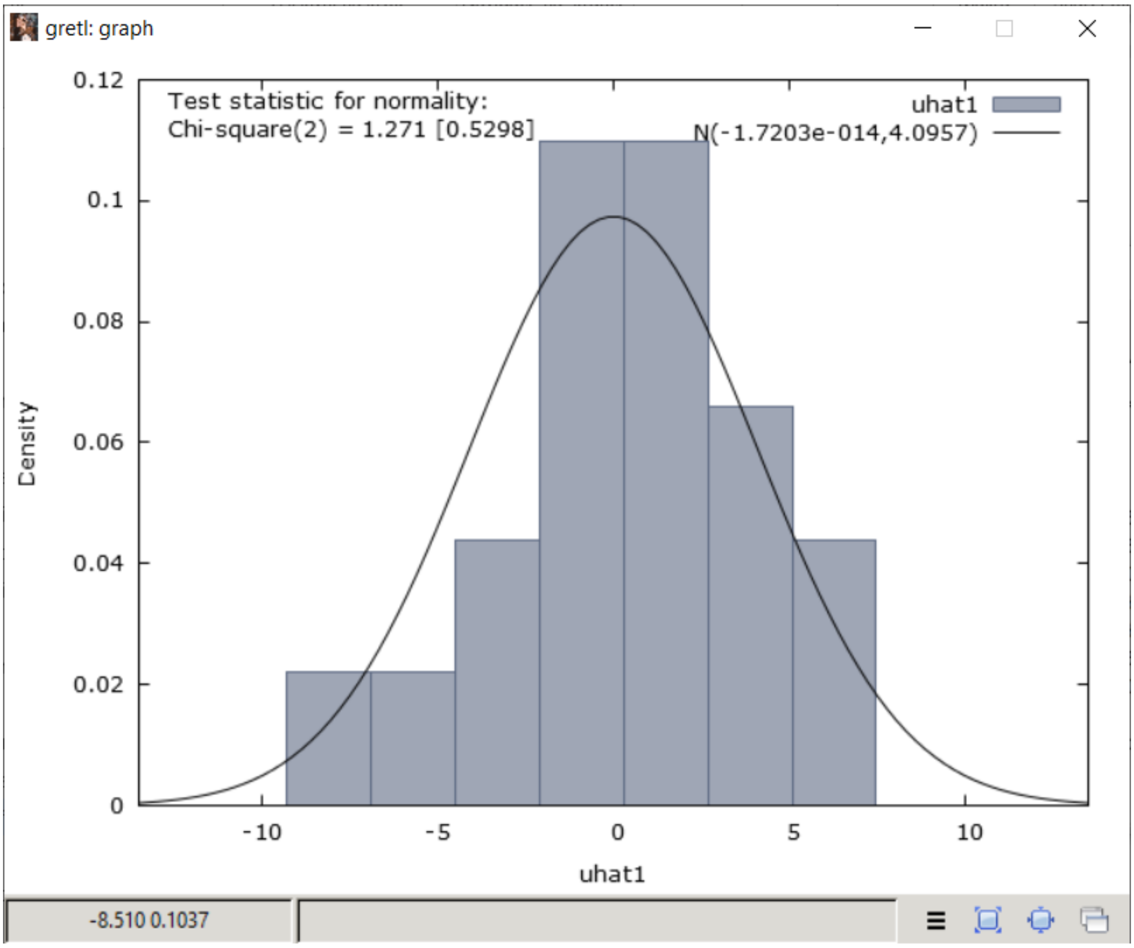
Picture 32: Normal Distribution of Residuals


gretl: residual dist.

```
Frequency distribution for uhat1, obs 1-19
number of bins = 7, mean = -1.72026e-014, sd = 4.09567

       interval          midpt   frequency    rel.     cum.

           < -6.8983    -8.0969        1      5.26%    5.26% *
   -6.8983 - -4.5011    -5.6997        1      5.26%   10.53% *
   -4.5011 - -2.1040    -3.3026        2     10.53%   21.05% ***
   -2.1040 -  0.29318   -0.90540       5     26.32%   47.37% *********
   0.29318 -  2.6903     1.4918        5     26.32%   73.68% *********
    2.6903 -  5.0875     3.8889        3     15.79%   89.47% *****
          >=  5.0875     6.2861        2     10.53%  100.00% ***

Test for null hypothesis of normal distribution:
Chi-square(2) = 1.271 with p-value 0.52977
```

Source: Gretl SW

Figure 11: Graphical illustration of ND of residuals



Source: Gretl SW

4.4.6 Model application

Coefficients of elasticity

The intensity of the effect of exogenous on endogenous variables is expressed, as elasticity, in the table below (*table 13*). This allows us to compare each exogenous variable. Calculations were done for year 2018.

Table 13: Elasticities

	CP PM
x2 (C PM)	-3,4497118
x3 (NP)	0,801219118
x4 (SP)	-1,25693838
x5 (CP RS)	0,274574115

Source: Excel; own elaboration

Example:

If the consumption of pork increases by 1%, the consumer price of pork decreases by 3.5%.

If the price of rape seed increases by 1%, the consumer price of pork increases by 0.3%.

Scenarios' simulation

Let's say the consumption of pork would increase by 15% in year 2019 and all other variables would remain constant. It would be calculated as 43.18*1.15 = 49.657

$$\hat{y}_{1(2019)} = 265.796 - 3.391 * 49.657 + 0.052 * 1557.218 - 0.055 * 2309.685 + 2.989 * 9.284 + \varepsilon_{1t} = 79.1$$

The drop in consumer price of pork meat from 102.8 to 79.1 (decrease by 29.98%).

Ex-post prognosis

Let´s reduce out set range of the last three years 2016, 2017 and 2018. For the calculation of prognosis, the Gretl software is used. The output is following *Picture 33* showing both, the point and 95% interval prediction for pork meat consumer price for years 2016, 2017 and 2018. The simple comparison of predicted values with actual values is possible.

Picture 33: Ex-post prognosis of Pork meat consumer price for years 2016, 2017 and 2018

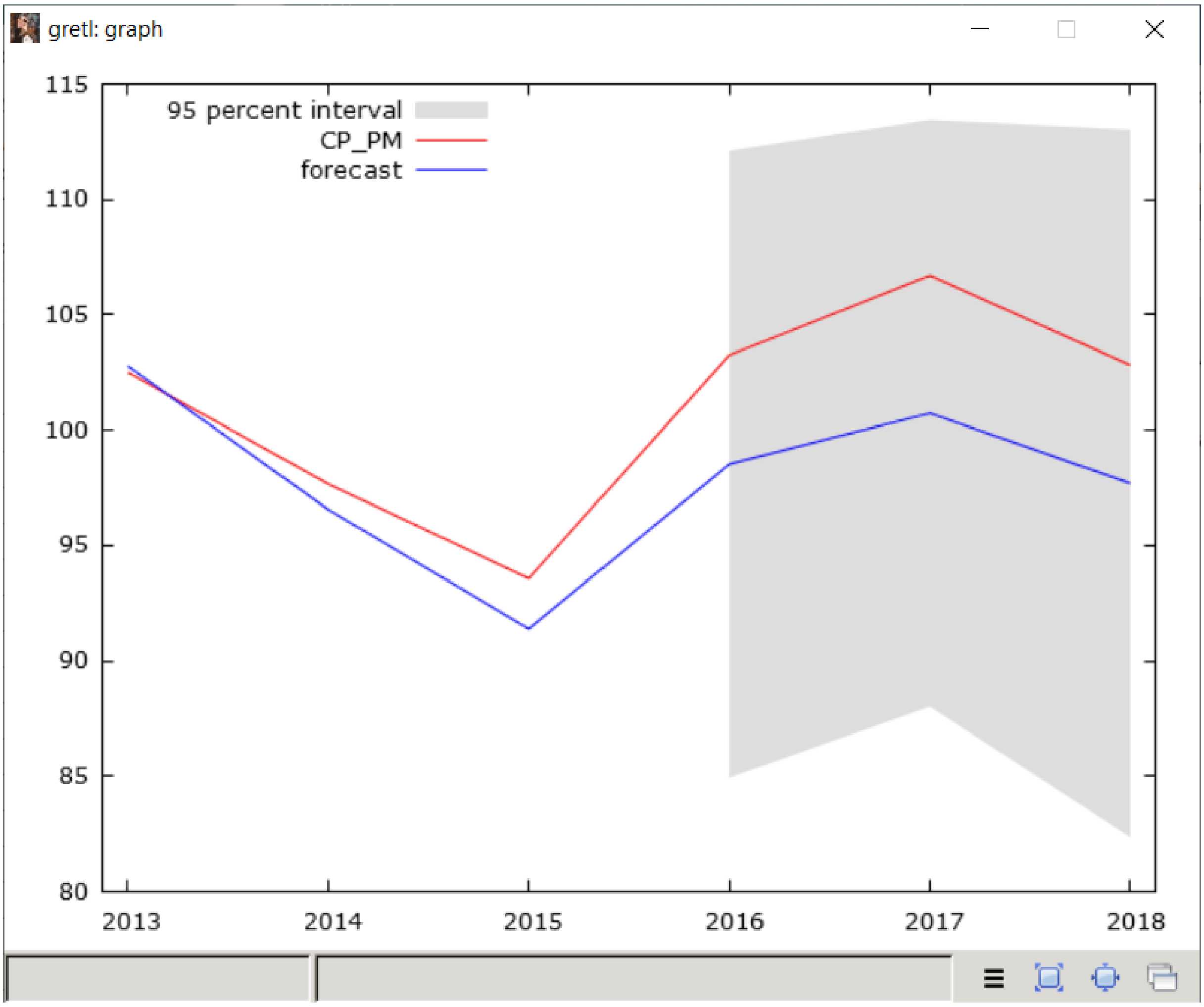
gretl: forecasts

```
For 95% confidence intervals, t(11, 0.025) = 2.201

            CP_PM    prediction    std. error        95% interval

2013      102.505      102.782
2014       97.665       96.556
2015       93.570       91.385
2016      103.245       98.522      6.1747      84.931 -  112.112
2017      106.700      100.731      5.7799      88.010 -  113.452
2018      102.815       97.690      6.9686      82.353 -  113.028

  Forecast evaluation statistics

  Mean Error                          5.2723
  Root Mean Squared Error             5.2978
  Mean Absolute Error                 5.2723
  Mean Percentage Error               5.0511
  Mean Absolute Percentage Error      5.0511
  Theil's U                           1.5199
  Bias proportion, UM                 0.99039
  Regression proportion, UR           0.0066431
  Disturbance proportion, UD          0.0029633
```

Source: Gretl SW

From the *Picture 33* is visible that the average price for pork meat per kilogram in year 2016 was CZK 103.2 next to the prognosis that predicts CZK 98.5. The same interpretation applies for year 2017 and 2018. Therefore, the prognosis is quite accurate as the difference is pretty small. Relative to our observations, our estimates are +5.05 away, which is the deviation and it means, our estimates are equivalent to 105.05% of the real observation (Mean percentage error in the *picture 33*). We can also observe, that overall, the forecast should be on average only 5.05% away from the actual observation that is represented by Mean absolute percentage error in the *picture 33*. The results are graphically introduced in *figure 12*, where we can observe that the red line (real prices of pork meat are within the 95% confidence interval). Therefore, the model is recommendable for further predictions.

Figure 12: Graphical illustration of ex-post prognosis of CP PM for 2016, 2017 and 2018



Source: Gretl SW

5 Conclusion

The aim of the thesis was to analyse the consumption of pork meat and its consumer price in the Czech Republic within limited time frame of years 2000 – 2018. Another goal was to determine which exogenous variables are affecting these endogenous variables. Data sets were collected primarily from the Czech Statistical Office and Ministry of Agriculture of the Czech Republic.

In the first part of the thesis, the literary research, there are described economic theories that are crucial as a basis for following analysis conducted in the second part, with explanation of basic market principles. The consumption is also described from a marketing perspective and econometric basics of modelling and derivation of forecast are described.

The chapter of the empirical part is divided into two phases. In the first phase the development of meat consumption individually for the mainly consumed kinds of meats and as whole, followed by the development of prices of pork was evaluated and compared based on elemental characteristics of time series. Time series of meat consumption were appointed by the most suitable trend functions. Based on that, the forecast of for the years 2019 and 2020 was elaborated by extrapolation. Development of time series of income in the Czech Republic was also introduced. The second phase presents three econometric models. Two of them are one equation models and one is multiple equations model. All of them contains the economic and econometric model presented together with the input data. The model was subsequently estimated and verified economically, statistically and econometrically. Models were applied for elasticities interpretation and estimation of future developments, scenarios simulations and ex-post prognosis.

In the first one equation model, there was analysed the *consumption of pork* in the Czech Republic and on its independent exogenous variables such as consumer price of beef, income and time trend. In the model, there was detected high multicollinearity among the price of beef and the income, which was later eliminated by transformation of one of these two variables by relative differences but due to this we lost one year of observation. Within the frame of economic verification, the economic assumptions defined at the beginning of the project were confirmed except one variable (consumer price of beef), where there was suggested the possible explanation of this phenomena and why it was not confirmed. The statistical verification showed insignificance of originally suggested variables such as consumer price of pork or consumer price of poultry, however, all of the other variables and its parameters proved the statistical significance. The quality of model was very good, since the R^2 was 70%.

In case of multiple-equations model, the *consumer price of pork* had been explaining as a dependent variable of the second equation. The data set had been modified due to the persistent multicollinearity among exogenous variables x_2 and x_3 from the first model. The transformed variable was an income by relative differences, which helped to successful elimination of the multicollinearity between these two variables, but one observation was lost by this doing again. In identification of the model, it was determined that both of the equations are over-identified. In the frame of statistical verification, in the 1st equation, the only variable x_2 (consumer price of beef) was considered as insignificant, while the others were found to be statistically significant. In the 2nd equation, only variables x_5 (number of pigs) and x_6 (slaughtered pigs) were found as statistically significant, on the contrary the x_7 (consumer price of rape seed) was found as insignificant. Coefficients of determination were in both equations very high, which indicated the strong dependency of endogenous on exogenous variables. Economic verification in the first equation showed that the consumer price of beef does not agree with the stated economic theory, the same result was found in the first phase of practical part of the thesis. In the second equation, number of pigs went oppositely to expected assumption. Otherwise, all stated economic assumptions agreed with our results. Based on econometric verification, in both equation there is no autocorrelation, there is homoscedasticity and the residuals have been normally distributed. Quality of the model is 83.3%.

Regarding the last, one equation model, the examined dependent variable was *consumer price of pork meat* in the Czech Republic. The independent exogenous variables were selected as consumption of pork meat, number of pigs, slaughtered pigs and price of rape seed. In the model, there was detected high multicollinearity among the variables number of pigs, slaughtered pigs and price of rape seed. Given the quality of the model that is 82.9% (R^2), the multicollinearity had not been eliminated and thus, there was no loss in observations. Considering the economic verification, the expected economic assumptions were all successfully confirmed with one exception of number of pigs, where there was suggested the possible explanation of this phenomena, why it was not confirmed. The statistical verification proven no insignificance of variables in the model. Therefore, all of the variables and its parameters proved the statistical significance.

In application of model there were found and expressed elasticities of the variables, the simulation of scenario had been applied and finally the ex-post analysis had been elaborated that confirmed its quality in all three cases where the prediction is not much different from the real values and therefore, can be recommended for further forecasts.

What is disturbing is the finding that the relationship between consumption of pork meat and its own consumer price was not proven. It might be caused by international trade, that the worldwide competition suppress the Czech farmers to lower the prices to the possible minimum that might not reflect the actual cost of production and the real value for the final products of certain quality. Also, the illnesses of animals accompanied by epidemies might cause the fear from buying such a good that might lead again to forcing the Czech farmers to decrease the prices to reduce the fear of consumers. It might be also given by a fact that no matter how much the pork meat costs, if it is still in the range of what consumers consider as acceptable, they are going to keep buying this commodity. Afterall, as the results of current situation of meat preferences show, the pork meat is the most favourite kind of meat of the Czech population throughout the time.

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7 List of Figures, Tables and Pictures

List of Figures

Figure 1: Annual consumption of pork per capita in kilograms (2000-2018)...................................... 58
Figure 2: Structure of overall meat consumption in the year 2000 in the Czech Republic 62
Figure 3: Structure of total meat consumption in the year 2018 in the Czech Republic...................... 63
Figure 4: Development of consumer prices of pork, beef and poultry in the Czech Republic (2000-2018)... 64
Figure 5: Development of income in the Czech Republic in years 2000-2018.................................... 65
Figure 6: Normality of Residuals – One-equation model 83
Figure 7: Graphical illustration of ex-post prognosis of CPM for 2018 86
Figure 8: Normal distribution of residuals from the 2nd equation 100
Figure 9: Normal distribution of residuals from the 1st equation 100
Figure 10: Graphical illustration of ex-post prognosis of CP PM for 2017 and 2018 104
Figure 11: Graphical illustration of ND of residuals.. 113
Figure 12: Graphical illustration of ex-post prognosis of CP PM for 2016, 2017 and 2018............. 116

List of Pictures

Picture 1: OLSM graphical depiction 9
Picture 2: Behaviour of total and marginal utility in Cardinal approach 22
Picture 3: Indifference curves in Ordinal approach 23
Picture 4: Correlation Matrix on the first model version 72
Picture 5: Correlation Matrix on the current model version 73
Picture 6: Correlation Matrix after Multicollinearity elimination.. 73
Picture 7: Data after Multicollinearity elimination 74
Picture 8: Estimation of parameters 75
Picture 9: Statistical verification of the model 77
Picture 10: Test of Autocorrelation... 81
Picture 11: Test of Heteroskedasticity 82
Picture 12: Normal distribution of Residuals.. 83
Picture 13: Ex-post prognosis of Pork meat consumption for year 2018... 85
Picture 14: Correlation matrix of the second function of Multiple-equations model........................... 90
Picture 15: Correlation matrix of the multiple-equations model.. 90
Picture 16: Parameters estimation of the 1st equation 92
Picture 17: Parameters’ estimation of 2nd equation 93
Picture 18: Statistical significance of the parameters from the first equation 94
Picture 19: Statistical significance of the parameters from the second equation 95
Picture 20: Autocorrelation of the 1st equation in Multiple - equations model 97
Picture 21: Autocorrelation of the 2nd equation in Multiple - equations model 98
Picture 22: Heteroscedasticity of the 1st equation from the Multiple - equations model 98
Picture 23: Heteroscedasticity of the 2nd equation from the Multiple - equations model 99
Picture 24: Normality test of the 1st equation in Multiple - equations model 99
Picture 25: Normality test of the 2nd equation in Multiple - equations model 100
Picture 26: Ex-post prognosis of Pork meat consumer price for years 2017 and 2018 103
Picture 27: Correlation matrix.. 108
Picture 28: Estimation of Parameters.. 109
Picture 29: Statistical significance of the parameters... 110
Picture 30: Test of Autocorrelation... 111

Picture 31: Heteroskedasticity 112
Picture 32: Normal Distribution of Residuals 113
Picture 33: Ex-post prognosis of Pork meat consumer price for years 2016, 2017 and 2018 115

List of Tables

Table 1: Data set of originally selected variables for the model 126
Table 2: Data set of current variables of the model 127
Table 3: Summary Statistics 71
Table 4: Statistical verification of selected models 78
Table 5: Statistical verification of selected models 79
Table 6: Data set of multi-equations model before Multicollinearity elimination 127
Table 7: Summary Statistics 89
Table 8: Data set of multi-equations model 91
Table 9: Model identification 92
Table 10: Coefficients of elasticity 102
Table 11: Data set of CP PM model 107
Table 12: Summary Statistics 108
Table 13: Elasticities 114

8 Appendix

Table 1: Data set of originally selected variables for the model

Year	C PM *[kg/y/capita]*	CP PM *[CZK/kg]*	C BM *[kg/y/capita]*	C ChM *[kg/y/capita]*	In *[thousand CZK]*
2000	40,90	97,635	12,300	22,300	13,219
2001	40,90	103,07	10,200	22,900	14,378
2002	40,90	81,195	11,200	23,900	15,524
2003	41,50	84,97	11,500	23,800	16,43
2004	41,10	90,935	10,300	25,300	17,466
2005	41,50	84,645	9,900	26,100	18,344
2006	40,70	84,655	10,400	25,900	19,546
2007	42,00	82,785	10,800	24,900	20,957
2008	41,31	87,27	10,140	25,000	22,592
2009	40,90	84,89	9,400	24,800	23,344
2010	41,59	81,015	9,400	24,500	23,864
2011	42,07	87,775	9,110	24,530	24,455
2012	41,29	99,18	8,100	25,190	25,067
2013	40,33	102,505	7,510	24,320	25,035
2014	40,72	97,665	7,860	24,890	25,768
2015	42,90	93,57	8,140	26,030	26,591
2016	42,84	103,245	8,470	26,780	27,764
2017	42,34	106,7	8,430	27,270	29,638
2018	43,18	102,815	8,740	28,400	31,868

Source: The Czech Statistical Office, own elaboration

Table 2: Data set of current variables of the model

Year	C PM [kg/y/capita]	CP PM [CZK/kg]	CP BM [CZK/kg]	CP ChM [CZK/kg]	In [thousand CZK]
2000	40,90	97,635	114,205	61,650	13,219
2001	40,90	103,07	106,785	60,550	14,378
2002	40,90	81,195	107,195	46,230	15,524
2003	41,50	84,97	107,025	53,600	16,43
2004	41,10	90,935	114,080	51,800	17,466
2005	41,50	84,645	119,065	51,600	18,344
2006	40,70	84,655	122,785	44,300	19,546
2007	42,00	82,785	124,275	61,470	20,957
2008	41,31	87,27	129,315	58,990	22,592
2009	40,90	84,89	132,135	56,180	23,344
2010	41,59	81,015	130,465	58,630	23,864
2011	42,07	87,775	138,380	58,490	24,455
2012	41,29	99,18	154,670	65,520	25,067
2013	40,33	102,505	157,285	69,630	25,035
2014	40,72	97,665	156,335	70,550	25,768
2015	42,90	93,57	155,615	66,300	26,591
2016	42,84	103,245	161,765	64,870	27,764
2017	42,34	106,7	168,160	67,640	29,638
2018	43,18	102,815	173,125	67,740	31,868

Source: The Czech Statistical Office, own elaboration

Table 63: Data set of multi-equations model before Multicollinearity elimination

Year	UV	C PM [kg/y/capita]	CP BM [CZK/kg]	In [thousand CZK]	TV	CP_PM [CZK/kg]	NP [thousand heads]	SP [thousand heads]	CP_RS [CZK/kg]
2000	1	40,90	114,205	13,219	1	97,635	3687,967	4513,596	6,099
2001	1	40,90	106,785	14,378	2	103,07	3593,717	4286,6	6,904
2002	1	40,90	107,195	15,524	3	81,195	3440,925	4407	6,467
2003	1	41,50	107,025	16,43	4	84,97	3362,801	4414	7,348
2004	1	41,10	114,080	17,466	5	90,935	3126,539	4085	7,183
2005	1	41,50	119,065	18,344	6	84,645	2876,834	3760	5,628
2006	1	40,70	122,785	19,546	7	84,655	2840,375	3721	6,657
2007	1	42,00	124,275	20,957	8	82,785	2830,415	3769	7,418
2008	1	41,31	129,315	22,592	9	87,27	2432,984	3508	9,785
2009	1	40,90	132,135	23,344	10	84,89	1971,417	3161	7,104
2010	1	41,59	130,465	23,864	11	81,015	1909,232	3034	7,737
2011	1	42,07	138,380	24,455	12	87,775	1749,092	2904	11,207
2012	1	41,29	154,670	25,067	13	99,18	1578,827	2656	11,843
2013	1	40,33	157,285	25,035	14	102,505	1586,627	2591	10,949
2014	1	40,72	156,335	25,768	15	97,665	1617,061	2640,128	9,724
2015	1	42,90	155,615	26,591	16	93,57	1559,648	2508,272	9,86
2016	1	42,84	161,765	27,764	17	103,245	1609,945	2427,517	10,128
2017	1	42,34	168,160	29,638	18	106,7	1490,775	2337,79	10,573
2018	1	43,18	173,125	31,868	19	102,815	1557,218	2309,685	9,284

Source: The Czech Statistical Office, own elaboration