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# PARTIAL EQUILIBRIUM MODEL – CASE STUDY OF THE POULTRY MARKET

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## Abstract

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This paper deals with identifying the main determinants in the poultry agri-food chain in the Czech Republic and examines their relationships. The partial equilibrium model, defined as a seven-equation model in power form, is employed for this purpose. The analysis is based on both time-series and panel data of the main factors in the poultry market. The time-series as well as panel data contain annual data of selected variables for the period from 1995 to 2009. The analysis is focused on supply and demand of poultry meat, specifically on production, consumption and foreign trade in poultry meat in the Czech Republic. Firstly, the main factors influencing the poultry market are determined, then, an appropriate model is employed. The parameters of the model are estimated using the ordinary least squares method in statistical and econometric software. Estimated parameters confirm assumed relationships among the selected variables. Moreover, the long-term tendencies of the selected indicators are proven. Among other, the analysis proves an inertial consumption, the price level as the main factor influencing the consumption and one-way or mutual relationship among the selected variables. The statistical features of the model are satisfied as well – the estimated parameters are statistically significant, the model does not contain, neither the problem of autocorrelation of residuals nor the problem of heteroskedasticity.

time series, panel data, partial equilibrium model, agri-food market, poultry

The poultry sector is one of the most important agri-food chains in the Czech Republic. Poultry meat, especially chicken meat, is favourite due to its features and characteristics connected with taste, nutritional content and fast preparation. According to Malý (2009), Čechura *et al.* (2010), Maier, Pánková (2010) and Janda (2010), among others, the poultry agri-food chain is the only meat sector in the Czech Republic with an increasing long-term tendency toward consumption and related indicators. Many factors influence production, processing and consumption of poultry meat, including input prices, consumer preferences and animal diseases. Niemi, Lehtonen, Pietola (2006) state that many studies have shown that an outbreak of highly contagious animal diseases has the potential to cause large losses for producers, the government and other stakeholders. Clark, Čechura (2011) confirm this statement using the example of beef meat and BSE disease. Furthermore, Miele (1999) and others emphasize the importance and influence of new factors and trends in meat production and consumption. For example, organic farming, the possibility of GMO (genetically modified organisms) production, and specific demands of consumers influence the extent and quality of supplied meat products.

Generally speaking, market equilibrium can be defined and analysed using the general or partial equilibrium model. All possible factors influencing the selected market can be defined and analysed using the general equilibrium model. The application of the general equilibrium model can be found in Berg, Reinert (1995) and in Křístková (2010) among others. The partial equilibrium model (PEM) generally describes the equilibrium in the selected

market. Analysis based on PEM omits the influence of other markets and other external factors. This paper deals with only the most relevant factors to describe the equilibrium in the Czech poultry market, one of the most important agri-food sectors in the Czech Republic. This means that the analysis is based only on the partial equilibrium model. Some examples of equilibrium modelling in meat markets that emphasize different factors can be found in Niemi, Lethonen, Pietola (2006), Andersen *et al.* (2007), da Silva e Souza *et al.* (2008), and others.

The background for the model determination can be found in Hušek, Pelikán (2003), for example. The theoretical background for econometric data processing and model verification can be found in Gujarati (1998), Hušek (1999), Seddighi *et al.* (2000) and Dougherty (2002), among others.

The aim of this paper is to define the main determinants in the poultry market in the Czech Republic, and to examine and explain the relationships among them using the partial equilibrium model.

## MATERIAL AND METHODS

The choice of variables and their relationships were defined based on the assumptions for the poultry market in the Czech Republic. The model employed is the final output of the whole process of model selection and construction. Firstly, more variables were included into the equations; however, the relationships were not proven and the results were insignificant. Then, this model was selected as the most suitable and the most significant to describe the relationships in analysed agri-food market.

To fulfil the aim of the paper several hypotheses were defined and verified subsequently. The hypotheses are focused mainly on consumption of chicken meat; nevertheless, the model describes and analyzes some other relations. The hypotheses were stated as follows:

- $H_1$: *The amount of production depends on its previous value which corresponds with the inertial character of consumption and nature of the poultry meat as a commodity.*
- $H_2$: *The price of chicken meat and income belong to the main determinants of the chicken meat consumption.*
- $H_3$: *The reaction of consumers on price level changes is inelastic; the value of coefficient of income elasticity reaches value higher than 0 and smaller than 1.*

The model describing partial equilibrium in the poultry agri-food chain is defined as a seven-equation model in power form as follows:

$$Plw_t = \alpha_1 \times FP_{t-1}^{\alpha_2} \times Plw_{(t-1)}^{\alpha_3} + \varepsilon_{1t}$$

$$P_t = \alpha_4 \times Plw_t + \varepsilon_{2t}$$

$$\mathrm{Im}_t = \alpha_5 \times C_{(t-1)}^{\alpha_6} \times \mathrm{Im}\, P_t^{\alpha_7} + \varepsilon_{3t}$$

$$HC_t = \alpha_8 \times CP_t^{\alpha_9} \times CPBM_t^{\alpha_{10}} \times In_t^{\alpha_{11}} + \varepsilon_{4t}$$

$$C_t = \alpha_{12} \times HC_t + \varepsilon_{5t}$$

$$Ex_t = \alpha_{13} \times P_{(t-1)}^{\alpha_{14}} \times Ex_{(t-1)}^{\alpha_{15}} + \varepsilon_{6t}$$

$$P_t + \mathrm{Im}_t + stock_t = C_t + Ex_t\,,$$

where

*a) endogenous variables:*

*Plw* ..... production of chicken meat (metric tons live weight)
*P* ..... production of chicken meat (metric tons)
*Im* ..... import of chicken meat (thousand metric tons)
*HC* ..... household consumption of poultry meat (kg/month/household)
*C* ..... consumption of chicken meat in the Czech Republic (thousand metric tons)
*Ex* ..... export of chicken meat (thousand metric tons)

*b) exogenous variables:*

*Fp* ..... farmer price of chicken meat (CZK/kg)
*ImP* ..... import price of chicken meat (CZK/kg)
*CP* ..... consumer price of chicken meat (CZK/kg)
*CPBM* .. consumer price of beef meat (CZK/kg)
*In* ..... income (thousand CZK/month/household)

*c) other:*

*t* ..... current period
(*t*–1) ..... lagged period (previous year)
$\alpha_1, \alpha_2, \ldots, \alpha_{15}$ ..estimated parameters
$\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{6t}$ ....error term.

The partial equilibrium model on the poultry meat market was derived on the basis of time series, as well as on the basis of panel data containing annual data for the years from 1995 to 2009. The data were provided by the Czech Statistical Office and by the Ministry of Agriculture. The panel data describing consumption come from the statistics of family accounts as registered by the Czech Statistical Office and contain values for 10 income groups within the examined time period from 1995 to 2009. The data characterize the consumption of poultry meat by individual households in the Czech Republic, as the consumption of chicken meat itself is not monitored in the statistics of family accounts. However, such fact may be disregarded, as approximately 90% of the consumption of poultry meat constitutes the consumption of chicken meat. Thus, such difference will not be taken into consideration in the following text. Individual equations of the defined model were estimated using the ordinary least squares method with the application of the Gretl and PC Give statistical and econometric software.

## RESULTS AND DISCUSSION

### I. Data Set Description

Tab. I contains the basic characteristics of the applied time series, specifically the mean value of the given time series, the minimum value, the maximum value, the standard deviation and the variation coefficient. All time series contain 15 observations. As is evident from the table, the least fluctuating in the monitored time period are the time series expressing the price of agricultural producers of chicken (FP) and the consumer price of chicken meat (CP) (the variation coefficient achieving a value of approximately 10 %), while the most fluctuating are the time series of the import and export of chicken meat (the variation coefficient exceeding the value of 77 %).

Tab. II contains the basic characteristics of the individual variables used in the consumption function on the basis of the statistics of family accounts, specifically the mean value of the given variable, the minimum value, the maximum value, the standard deviation and the variation coefficient. All of the variables contain 150 observations. As it is evident from the table, the least fluctuating in the monitored period of time are consumer prices (CP PM, CP BM) (the variation coefficient achieving values of 10.22, or 7.77 %) and the most fluctuating is the variable of income (the variation coefficient achieving a value of 47.77 %).

### II. Partial Equilibrium Model

The individual equations of the estimated partial equilibrium model for the chicken meat market in the Czech Republic are described in the following section. As mentioned before, the model contains seven equations and has been estimated in power form. The explanatory variables included in the individual equations of the model have been chosen according to economic hypotheses. The resulting form of the model contains only the factors that affect the individual explained variables in a significant manner which was verified by way of a statistical verification.

#### *1 Production of chicken meat*

$$Plw_t = 0.327057 \times FP_{t-1}^{0.510102} \times Plw_{(t-1)}^{0.919353}$$

The first equation of the partial equilibrium model describes the dependence of the production of chicken meat in live weight ($Plw_t$) on the price of agricultural producers in the previous period ($FP_{(t-1)}$) and on the production of chicken meat in live weight in the previous period ($Plw_{(t-1)}$). In view of the nature of the time series that were used for the estimation of the model, there is a lag of one year. However,

I: *Descriptive Statistics of Time Series*[1]

| Variable | Mean | Std. deviation | Minimum | Maximum | Variation coefficient (%) |
|---|---|---|---|---|---|
| Production (thousand t live weight) | 222.44 | 50.06 | 132.85 | 275.65 | 22.50 |
| Production (thousand t) | 166.83 | 37.54 | 99.64 | 206.74 | 22.50 |
| Consumption (thousand t) | 181.39 | 45.46 | 99.72 | 229.79 | 25.06 |
| FP (CZK/kg) | 22.72 | 2.39 | 19.21 | 27.58 | 10.50 |
| CP (CZK/kg) | 54.73 | 6.09 | 46.80 | 66.22 | 11.13 |
| Import (thousand t) | 24.97 | 19.46 | 3.85 | 58.97 | 77.93 |
| Export (thousand t) | 11.10 | 8.58 | 1.38 | 23.76 | 77.30 |
| Import price (CZK/kg) | 47.96 | 10.47 | 35.84 | 68.84 | 21.83 |

Source: Czech Statistical Office, Ministry of Agriculture

II: *Descriptive Statistics of Panel Data*[2]

| Variable | Mean | Std. deviation | Minimum | Maximum | Variation coefficient (%) |
|---|---|---|---|---|---|
| Consumption (kg/month/household) | 14.62 | 3.35 | 7.33 | 23.74 | 22.90 |
| CP PM (CZK/kg) | 64.77 | 6.62 | 51.26 | 78.52 | 10.22 |
| CP BM (CZK/kg) | 113.34 | 8.81 | 95.71 | 137.24 | 7.77 |
| Income (thousand CZK/month/household) | 104.73 | 50.03 | 31.21 | 309.56 | 47.77 |

Source: Czech Statistical Office – Statistics of Family Accounts

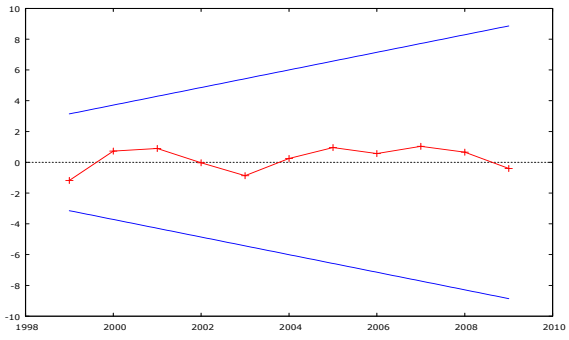
1 The individual variables pertain to chicken meat. FP = price of agricultural producers (farmer price), CP = consumer price.

2 The individual variables pertain to chicken meat. CP = consumer price, PM = poultry meat, BM = beef meat.

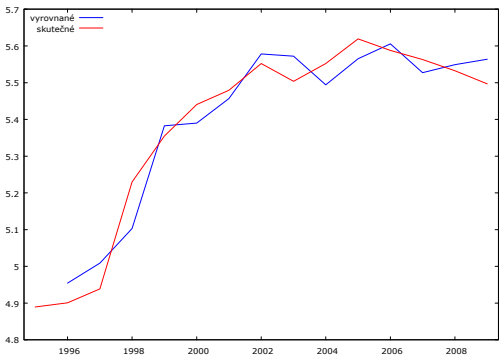
in view of the nature of the model, it would be more appropriate to consider the duration of one production cycle, but the available data do not allow for that directly. Nevertheless, it may be assumed, in a simplified sense, that the relationships that this model corresponds to relationships with a lag of one production cycle. This assumption will be reflected in the following commentaries.

The estimated model shows that the increase in both explanatory variables will cause an increase in the production of chicken meat in the current period. However, production in the previous period (parameter value 0.9194) shows more significant effect on production in the current period than the price of agricultural products in the previous period (parameter value 0.5101). In both cases, the reaction is inelastic, but the relationship between production in the previous and current period is almost proportional. Thus, it may be concluded that if the production of chicken meat is not affected by unexpected and unforeseen circumstances (e.g. bird flu or diseases relating to competing types of meat), its growth will be almost linear.

As regards the statistical verification of the model, it may be stated that the model achieves satisfactory results. The estimated parameters are statistically significant at a significance level of $\alpha = 0.01$, except the intercept term[3]. Further, the equation does not show the presence of heteroskedasticity or of residual autocorrelation, the estimate is stable (see Fig. 1a) and discrepancies between actual and theoretical values are insignificant (see Fig. 1b). The adjusted determination index reaches a value of 0.9219.




1a: *Estimate stability*




1b: *Actual and fitted values*
Source: authors' calculation

### 2. Production of chicken meat

$$P_t = 0.75 \times Plw_t$$

The second equation of the derived model shows that the production of chicken meat ($P_t$) equals 75% of the live weight of raised chicken broilers. Thus, the equation shows the technological relationship between the raising of live chickens and their processing into meat, i.e. its yield.

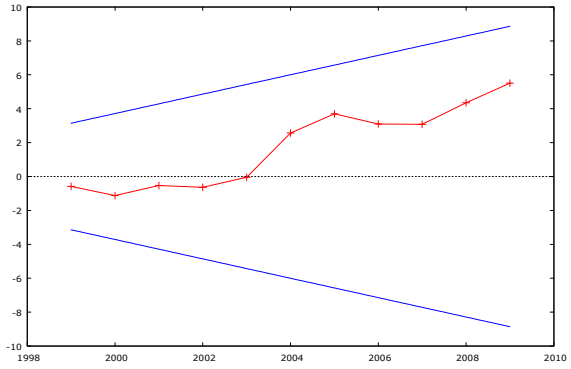
### 3. Import of chicken meat

$$\mathrm{Im}_t = 0.018735 \times C_{(t-1)}^{1.26329} \times \mathrm{Im}\, P_t^{-0.398183}$$

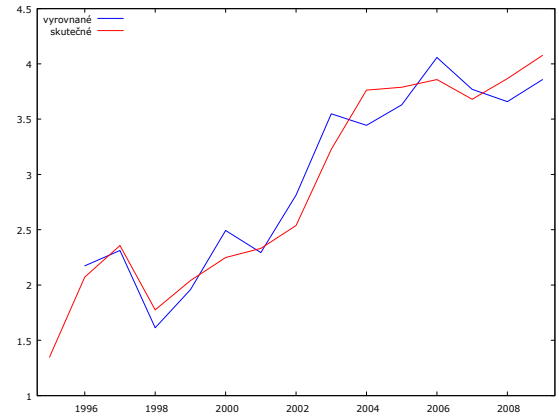
This equation describes the dependence of the import of chicken meat ($Im_t$) on the domestic consumption of chicken meat in the previous period ($C_{(t-1)}$) (lag duration – see above) and on the import price ($ImP_t$). The estimate shows that domestic consumption is the main factor for the imported amount of chicken meat. The parameter value of 1.2633 expresses a constant tendency between consumption and import and indicates an effort on the part of importers to place an increased amount of imported goods on the domestic market, as increased consumption in the previous period evokes the vision of their sales. As the derived model further shows, the import price is not quite as important in making such decisions. The parameter only achieves a value of –0.3982, so an increase or decrease in the import price should not cause a highly significant fluctuation in the imported amount. Thus, it may be stated that the import price is a significant factor for import, but its main determinant is domestic consumption.

The statistical properties of the estimated function are satisfactory. All of the parameters are not statistically significant at a significance level of $\alpha = 0.01$[4]. The equation does not show signs of heteroskedasticity, the estimate is stable (see Fig. 2a) and discrepancies between actual and theoretical values are insignificant (see Fig. 2b). The adjusted index of determination reaches a value of 0.9298.

3 P-value of intercept term equals 0.3247, P-value of $FP_{(t-1)}$ parameter 0.0000 and P-value of $Plw_t$ 0.0566.
4 P-value of intercept term equals 0.5341, P-value of $C_{(t-1)}$ parameter 0.1571 and P-value of $Im_t$ 0.7313.




2a: *Estimate stability*




2b: *Actual and fitted values*
Source: authors' calculation

### 4. Consumption of poultry meat by households[5]

$$HC_t = 0.00000853 \times CP_t^{-0.42822897} * CPBM_t^{0.29127168} \times In_t^{0.48469949}$$

The consumption function describes the dependence of the consumption of poultry meat by households ($HC_t$) on the consumer price of poultry meat ($CP_t$), the consumer price of beef meat ($CPBM_t$) and income ($In_t$). The function proves the presumed inverse character between the consumption of poultry meat and its price. The value of the coefficient of elasticity of –0.4292 further shows the inflexible inelastic reaction of consumers to a change in the price of poultry meat. In view of the fact that poultry meat may be considered basic (essential) goods, this reaction is in accordance with the assumptions and economic principles. The estimated parameter of 0.2913, which expresses the value of cross price elasticity, shows the substitutional nature of poultry and beef meat. However, the value of the coefficient is relatively low, and thus the reaction of consumers to a change in the price of beef is not very significant either. The parameter value of 0.4847 proves an increase in the consumption of poultry meat with an increase in income and an inelastic reaction on the part of consumers. However, that can only be assumed up to a certain level of consumption. In view of the nature of this commodity, it may be assumed that with increasing income, the consumption of poultry meat will only grow up to the so-called saturation level. Above that level, consumers will spend further income on other goods, relatively essential or luxury, which have not yet reached saturation.

The equation estimated has good statistical features, an autocorrelation of residuals does not occur as well as the problem of heteroskedasticity. All parameters are statistically significant at a significance level of $\alpha = 0.01$ or $\alpha = 0.1$ respectively[6]. The adjusted index of determination reaches a value of 0.8250.

### 5. Domestic consumption of chicken meat

$$C_t = 1236027 \times HC_t$$

This equation expresses the relationship between the total consumption of chicken meat ($C_t$) and the consumption of poultry meat by individual households in the Czech Republic ($HC_t$).

### 6. Export of chicken meat

$$Ex_t = 0.000667 \times P_{(t-1)}^{1.60686} \times Ex_{(t-1)}^{0.626746}$$

This equation describes the dependence of the export of chicken meat ($Ex_t$) on the production ($P_{(t-1)}$) and export ($Ex_{(t-1)}$) in the previous period (lag duration – see above). Undoubtedly, the share of the domestic price and the world price as well as the export price itself also has an effect on export. However, as the model shows, the production and exported amount in the previous period are among the most significant factors for the export of chicken meat from the Czech Republic.[7] That shows a constant tendency in the export of chicken meat. The estimated parameters of the model show a more significant effect of the production of chicken meat in the previous period (a parameter value of 1.6069)

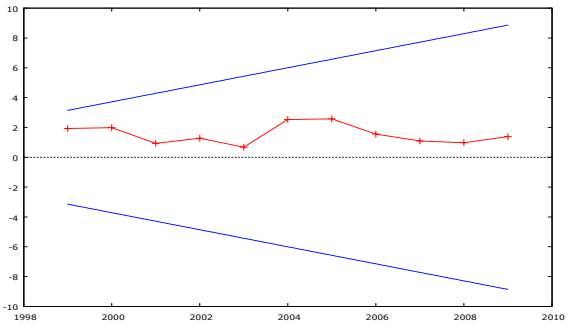
5 As stated above, the consumption function was estimated on the basis of data for poultry meat, but the difference between the consumption of chicken and poultry meat may be disregarded in view of the minimal discrepancies in the absolute expression as well as in long-term development tendencies.

6 P-value of intercept term equals 0.0000, P-value of $CP_t$ parameter 0.0000, P-value of $CPBM_t$ 0.0993 and P-value of $In_t$ 0.0000.

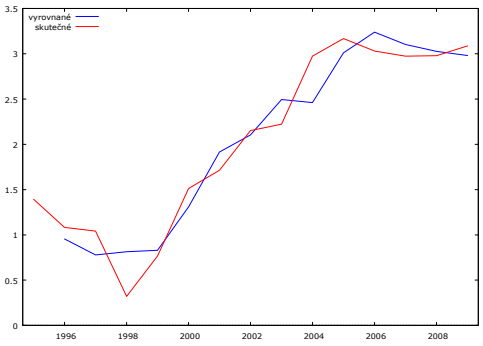
7 In deriving the partial equilibrium model, the export equation was also taken into consideration, with the inclusion of the effect of the export price. However, in the case of this variable, no significant effect on the amount of export was shown, and thus it was eliminated from the analysis.

on export in the current period than of its amount in the previous period (a parameter value of 0.6267). In view of the value of the parameter for production, which exceeds the level of 1, it may be stated that the demand for chicken meat in the Czech Republic is more or less satisfied (from domestic as well as foreign sources) and any increase in production thus shows up positively in the exported amount.

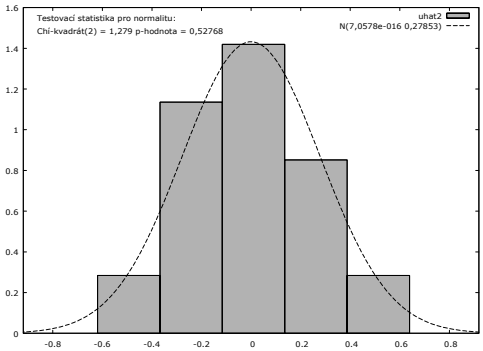
The estimated function also shows satisfactory qualities in regard to statistical verification. All of the estimated parameters are statistically significant at a significance level of $\alpha = 0.01$[8]. The model is free of heteroskedasticity, autocorrelation residuals, the estimate is stable (see Fig. 3a), discrepancies between the actual and theoretical values are not significant (see Fig. 3b) and the error term has a normal distribution (see Fig. 3c). The adjusted determination index reaches a value of 0.9218.




3a: *Estimate stability*




3b: *Actual and fitted values*




3c: *Error term distribution*
Source: authors' calculation

### 7. *Balance equation*

$$P_t + \mathrm{Im}_t + stock_t = C_t + Ex_t$$

The last equation of the model expresses a state of equilibrium where the supply of chicken meat is consistent with its demand.

## CONCLUSION

The aim of the paper was to define and examine the main determinants in the poultry market in the Czech Republic. The partial equilibrium model was defined and estimated based on the time series and panel data of selected variables for the poultry market in the Czech Republic in the period from 1995 to 2009. Firstly, the main factors of the poultry market were determined and then, their relationships were analysed. The analysis of the selected market was based on both, the time series and panel data of selected variables. Using the seven-equation model, supply and demand of poultry meat in the Czech Republic were examined. Concretely, individual equations of the model were focused on the production of poultry meat, its consumption and foreign trade. The estimated model confirmed long-term tendencies in the production and consumption of poultry meat. The importance of the main factors of consumption - price and income, were verified as well. Both factors are crucial; however, the reaction of consumers is inelastic due to the nature of the analyzed commodity. Moreover, a substitutional relationship between poultry and beef was proven. The extent of domestic consumption was determined to be the main factor in poultry imports, whereas the production of poultry meat and its exported amount in previous periods were the main determinants of poultry exports.

All hypotheses stated were accepted. The relationship between the production of chicken meat and its previous amount was proven. This result shows the inertial nature of the chicken meat consumption and production. The other hypotheses proved the assumptions about the reaction of consumers and the nature of an analyzed commodity. The price of the poultry meat might be labelled as the most significant determinant of the poultry consumption. However, poultry meat is relatively essential commodity and thus, the reaction of consumers on price changes is inelastic, as the model proved. According to Lechanová (2006) the consumers' sensitivity is important especially in

8 P-value of intercept term equals 0.0000, P-value of $P_{(t-1)}$ parameter 0.0005 and P-value of $Ex_{(t-1)}$ 0.0002.

the case of food safety. The key role of price as well as the importance of the meat quality, consumer habits and the availability of the various meats was proven in Janda (2010). The relationship between the consumer prices of poultry and beef meet was proved also in Malý (2009). Moreover, that research proved the mutual relationship between the poultry consumer price and the pork meat consumer price, contrary to the results of this paper.

In conclusion, we may state that the partial equilibrium model for the poultry meat market in the Czech Republic, derived on the basis of available annual data for the years from 1995 to 2009, illustrates the most significant factors that have an effect on the forming of supply and demand. The model shows the main determinants of the production of poultry meat, its foreign trade as well as the basic consumption tendencies. From a statistical perspective, the model shows good properties.


## SUMMARY

This paper deals with the poultry market equilibrium in the Czech Republic. The poultry agri-food chain belongs to the most important agricultural sectors in the Czech Republic, thus, the analysis of its determinants and market equilibrium is crucial for the producers, stakeholders as well as the policy makers. The aim of the paper is to identify the main determinants of the selected agri-food chain and to compose a model to describe and explain the relationships among them. Firstly, the main factors of poultry agri-good chain are determined, then, an econometric model is defined. The suitable model to analyse the relationships among the selected determinants of this agri-food chain is estimated in form of seven-equation model in power form using ordinary least squares method. Econometric and statistical software Gretl and PC Give are used for this purpose. The model is estimated based on both time series and panel data of the selected variables. Time series and panel data of selected variables contain annual data in period from 1995 to 2009. The analysed time series contain 15 observations while the panel data contain 150 observations (annual data for 10 income groups). The estimated model analyses supply and demand of the poultry meat in the Czech Republic. Individual equations are focused mainly on production of poultry, its consumption and foreign trade. The analysis confirms the assumed influence of the main determinants on selected endogenous variables in selected agri-food chain. Moreover, the model proves the long-term tendencies of the selected indicators. The statistical significance of the estimated model is verified as well.



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