POULTRY MEAT VERTICAL – A PARTIAL EQUILIBRIUM MODEL APPROACH*

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The main goal of the presented paper is to propose, specify, and quantify a model of partial equilibrium in the poultry meat vertical in the Czech Republic. Characterized within the analyzed relations in the commodity vertical will be demand-offer relationships on partial levels of the commodity chain on the basis of which the functional relations of the simultaneous model of the above-mentioned market will subsequently be specified. The quantified model makes it possible to define and describe the main determinants of the poultry offer and demand. The data used were acquired from the Situation and Forecast Reports (2010) (Ministry of Agriculture of the Czech Republic), from the Annual Reports on the State of Agriculture (2010) (Institute of Agricultural Economics and Information), and from the public statistics (available at www.czso.cz) (Czech Statistical Office), for the period 1995–2011. With regard to respecting the simultaneous relationships, the model estimate was carried out by means of the two-level method of least squares with subsequent statistic-econometrical verification. The acquired model shows sufficient robustness for market analyses and possible simulation calculations.

partial equilibrium model; poultry; farmer; producer; consumer; agrifood chain

INTRODUCTION

The production of poultry meat (or chicken meat) is a sector of animal production that has experienced great changes in its scope, structure as well as utilized technologies within the past two decades.

According to the register of farm animals within the analyzed period, first, in 2002, there was a stop to the constant increases in the numbers of poultry, which were already beyond the absorption capabilities of the market, and then, within the subsequent years, the numbers basically went down to the initial level, and according to the indicators for the year 2011, the decline in numbers is continuing further. The year 2002 was a significant change, when numbers began to decline as a result of, on the one hand, the worldwide decline in the demand for meat, which was also seen on the Czech market and, on the other, as a result of a significant decrease in farm prices, which got under the threshold of profitability and a number of businesses were forced to terminate production. However, the development of production does not correspond to the decline in numbers, as production did also show a decline, but not at such a rate. In the area of the yearly consumption of poultry meat, the value of 23 kg per capita was achieved in 2001 and thereby exceeded the average level of EU consumption. The said aspect was considered to be a positive trend, because in view of the dietary properties of poultry meat, the replacement of dietetic types of meats for cheap but lower quality types of other meats is considered to be a good step toward the rationalization of consumption behaviour and an improvement in the health situation of the population. Within the subsequent years, annual consumption once again oscillated around 23.5 kg per capita, and in the year 2005 it actually reached a level of approximately 25 kg per capita, which, according to the estimates at that time (e.g. M a l ý , 2009), already constituted the saturation level when consumption also started to go down.

The anticipated production in subsequent years will likely continue to decline, for several reasons. One of the main causes may be considered the long-term decreases in the price of agricultural producers, primarily of slaughterhouse chickens. The current level is already, in a number of cases, below the threshold of profitability, which is also manifested through the decline in the purchase of slaughterhouse poultry. Further, the issue is also the above-mentioned decrease in the consumption of poultry meat as a result of the saturation of the market and, at the same time, other dietetic types of meat are also asserting themselves,

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which, even despite the significant tradition of red meats in the Czech Republic, are showing up more and more often in the regular menu, as their availability on the market has improved significantly (see e.g. Malý, Kroupová, 2006). The present article is primarily motivated by the lack of demonstration of the use of partial equilibrium approach to agri-food market in the emerging economies of the EU. At the same time the achieved results extend the knowledge base for the subsequent broader research of selected commodity chain.

Finally, the main aim of this paper is to analyze the sectoral relationships in the vertical poultry in the Czech Republic using the partial equilibrium model approach.

MATERIAL AND METHODS

The conducted analysis of the poultry meat commodity vertical was based on the principles of the partial equilibrium commodity model (see e.g. Labys, Pollak, 1984), respecting three levels of the product vertical on a given market. At each level, supply-demand relationships are created, and those also have further mutual interconnections even between individual entities on various levels of the vertical, whereby simultaneous relationships arise that affect the overall concept of the model. According to Hallam (1990), four basic types of commodity models can be classified depending on the utilized analytical form of the functional relationships and the manner of (non) inclusion of the factor of time. Within the said classification, the applied partial equilibrium model can be indicated as being linear, simultaneous, and dynamic, as it includes forward links as well as backward links between the explained variables with the simultaneous utilization of the linear function form and the inclusion of a time vector including a time differentiation of the explanatory variables. In the literature, there can be found a number of advanced functional forms such as Cobb-Douglas, CES, translog, etc., but in the presented paper the basic linear model has been selected to simplify the model and to determine only the basic functional influences and links. Linear model is, however, successfully used also in other publications (Nissanke, Mavrotas, 2010; Schmitz et al., 2010, a.o.). Finally, the application of partial equilibrium models in different verticals and different markets can be found in numerous professional publications (Dillen et al., 2008; Malaga et al., 2010; Regorsek et al., 2011; Valdivia et al., 2012; Choi et al., 2013; Latta et al., 2013, etc.).

The basic level of the vertical form the agricultural producers, in the model portrayed as entities offering broilers for the purpose of slaughterhouse processing. The behaviour of the said businesses at the farm level is determined by the assumption of an adaptive price expectation of the said entities (Nerlov, 2001), and thus, in terms of functional relationships, the supply of slaughterhouse animals is affected by the buyout price from the preceding period, by the level of demand on the part of processors, as well as the quantity of import (TARIC classification), which currently significantly supplements the overall domestic supply. In view of the fact that out of the entire volume of import chicken meat is absolutely the majority component (see e.g. Peterson, Orden (2005)), customs groups corresponding exclusively to chicken meat have been adequately included (see correlation (1)). For the expression of the agricultural producer price, the import price, the processor price, and the industrial feed producer price were included among the explanatory variables (see correlation (2)). The said correlations characterize the farm level, which constitutes the supply portion for the demand of the ensuing processor level.

Farm level

$$Q_{SA,PLM,t} = f\left(PAP_{PLM,t-1}, Q_{DP,PLM,t}, Q_{IM,CHM,t}\right) \quad (1)$$

where:

$Q_{SA,PM,t}$ = supply quantity of poultry meat offered by producer (thousands of t of live weight)

$PAP_{PLM,t}$ = agricultural chicken meat producer price derived from (2) (CZK $t^{-1}$of live weight)

$Q_{DP,PLM,t}$ = demand quantity of chicken meat required by processor derived from (5) (thousands of t of live weight)

$Q_{IM,CHM,t}$ = import of chicken meat (selected customs groups) (thousands of t)

$$PAP_{PLM,t} = f\left(IPK_{PLM,t}, PP_{PLM,t}, PP_{f,t}\right) \quad (2)$$

where:

$PAP_{PLM,t}$ = agricultural poultry meat producer price (CZK t^{-1} of live weight)

$IPK_{PLM,t}$ = import price of chicken meat (CZK t^{-1})

$PP_{PLM,t}$ = processor price (average) of chicken meat derived from (6) (CZK t^{-1})

$PP_{f,t}$ = industrial producer price – feed mixture (average) (CZK t^{-1})

The modelled poultry meat market is, within the environment of the national economy of the Czech Republic, significantly determined by foreign trade, and thus it is also conceived as open in the model. The foreign sector can have a significant effect on both the supply side – primarily at the processor level, as well as on the demand side – primarily at the consumer level, but once again also at the processor level. According to a number of studies on agricultural foreign trade (e.g. a comprehensive FAO study

by Sarris, Hallam, 2006), correlations (3) and (4) were used for the expression of import and export of beef, whereby the import of poultry meat is determined by the quantity of demand for chicken meat on the part of the consumer, by the import price of chicken meat, and by the quantity of the domestic slaughter of broilers. The export of poultry meat is explained in the model by way of a dummy variable in the form of the proportion of the import and export price of chicken meat, and once again by the size of the domestic slaughter of broilers.

Import of meat

$$Q_{IM,PLM,t} = f\left(IPK_{PLM,t}, DS_{PLM,t}, Q_{DC,PLM,t}\right) \quad (3)$$

where:

$Q_{IM,PLM,t}$ = imported quantity of poultry meat (thousands of t of slaughterhouse weight)

$Q_{DC,PLM,t}$ = chicken meat demand quantity derived from (7) (thousands of t of slaughterhouse weight)

$IPK_{PLM,t}$ = import price of chicken meat (CZK t^{-1})

$DS_{PLM,t}$ = domestic slaughter of broilers (thousands of t of slaughterhouse weight)

Export of meat

$$Q_{EX,PLM,t} = f\left(\frac{IPK_{PLM,t}}{EPK_{PLM,t}}, DS_{PLM,t}\right) \quad (4)$$

where:

$Q_{EX,PLM,t}$ = exported quantity of poultry meat (thousands of t of slaughterhouse weight)

$IPK_{PLM,t}$ = import price of chicken meat (CZK t^{-1})

$EPK_{PLM,t}$ = export price of chicken meat (CZK t^{-1})

$DS_{PLM,t}$ = domestic slaughter of broilers (thousands of t of slaughterhouse weight)

The subsequent level of the vertical represents slaughterhouse processing, or meat processing plants, which include the slaughterhouse processing of purchased amounts of animals, whereby the product can be the slaughterhouse-processed trunk, statistically monitored under the indicator of domestic slaughter, which can itself be the object of both foreign trade, as well as domestic demand of the subsequent elements of the vertical. Nevertheless, the primary processing of the slaughterhouse trunk is usually accompanied by the subsequent processing and production of individual parts of chilled or frozen meat, or other kinds of intermediate products, which are a standard product of the supply at the processor level, for both external meat-butchery plants, as well as for the end consumer. According to Hallam (1990), the amount of the supply of jointed meat is affected by a whole range of exogenous as well as endogenous effects, whereby for the conceived model (correlation (5)), in view of the specific properties of the food product market in the Czech Republic, the endogenous effects of the quantity of imported chicken meat derived from correlation (3) and the amount of the consumers' demand according to correlation (7) were used. The processor price of the industrial producer (correlation (6)) is then once again determined by the proportion of the import price and the export price of chicken meat, for the purpose of the expression of the price transmission with the consumer price and, for the expression of long-term effects, also by way of a time vector. The said price transmission occurs at all levels of the vertical, but the process and direction of the procedure is the most easily discoverable at the processor level, which is based on a number of studies conducted on the meat market in the Czech Republic (Malý, 2009; Rumánková et al., 2012; Lechanová, 2006).

Processor level

$$Q_{DP,PLM,t} = f\left(Q_{IM,CHM,t}, Q_{DC,PLM,t}\right) \quad (5)$$

where:

$Q_{DP,PLM,t}$ = quantity of chicken meat demand by processors

$Q_{IM,CHM,t}$ = imported quantity of chicken meat (thousands of t of slaughterhouse weight)

$Q_{DC,PLM,t}$ = quantity of poultry meat demand by the consumer derived from (7) (thousands of t of slaughterhouse weight)

$$PP_{PLM,t} = f\left(\frac{IPK_{PLM,t}}{EPK_{PLM,t}}, CP_{PLM,t}, T\right) \quad (6)$$

where:

$PP_{PLM,t}$ = processor price (average) of chicken meat (CZK t^{-1})

$CP_{PLM,t}$ = consumer price (average) of chicken meat derived from (8) (CZK t^{-1})

$IPK_{PLM,t}$ = import price of chicken meat (CZK t^{-1})

$EPK_{PLM,t}$ = export price of chicken meat (CZK t^{-1})

T = time vector (proxy variable of technological changes)

According to classic microeconomic theory (see e.g. Varian, 1992), the final processor supply is followed by the partial consumer demand, which is, however, because of the broad assortment of meat products, statistically abstracted into the comprehensive indicator of the consumption of poultry meat. According to similarly conceived partial equilibrium models (see e.g. Moro et al., 2002) and on the basis of microeconomic theory, the consumer demand according to correlation (7) is dependent on the consumer price of beef meat, on the consumer price of poultry

meat, and on the consumer price of pork meat. The consumer price of poultry meat is then, according to correlation (8), dependent on the processor price of chicken meat, on the consumer price of beef meat, and on the proportion of the import price and the export price, expressing the motivation of the foreign sector to enter the domestic market and to thereby also influence the consumer price (see e.g. Schaffer, 2008).

Consumer

$$Q_{DCD,PLM,t} = f\left(CP_{BM,t}, CP_{PLM,t}, CP_{PM,t}\right) \quad (7)$$

where:

$Q_{DCD,PLM,t}$ = poultry meat demand quantity (thousands of t per year)

$CP_{BM,t}$ = consumer price of beef (CZK t^{-1})

$CP_{PLM,t}$ = consumer price of poultry meat derived from (8) (CZK t^{-1})

$CP_{PM,t}$ = consumer price of pork meat (CZK t^{-1})

$$CP_{PLM,t} = f\left(PP_{PM,t}, CP_{PLM,t}, \frac{IPK_{PLM,t}}{EPK_{PLM,t}}\right) \quad (8)$$

where:

$CP_{PLM,t}$ = consumer price of chicken meat (average) (CZK t^{-1})

$PP_{PLM,t}$ = processor price of chicken meat (average) derived from (6) (CZK t^{-1})

$CP_{BM,t}$ = consumer price of beef (CZK t^{-1})

$IPK_{PLM,t}$ = import price of chicken meat (CZK t^{-1})

$EPK_{PLM,t}$ = export price of chicken meat (CZK t^{-1})

For the expression of the equilibrium state, the model was supplemented with the balance identity (9) covering the model.

Balance

$$Q_{IM,PLM,t} + Q_{DP,PLM,t} = Q_{DC,PLM,t} + Q_{EX,PLM,t} \quad (9)$$

As has already been stated, in favour of simplification of the basic output, the utilized analytical form of the conceived model was the linear function, and a two-step least squares method (TSLS) was used for the estimate, which belongs to methods with limited information, but, nevertheless, it was applied within the environment of the Gretl 1.8.7. program by way of a one-time estimate of simultaneous equations. The congruity of estimated equations with data is standardly quantified by way of the tested adjusted coefficient of determination, and the statistical verification of the estimated parameters was conducted on the basis of the *t*-test. The defined econometric assumptions of the linear model were verified by way of standard methods for simultaneous models (Kenedy, 2008). Multi-co-linearity was tested by way of the Farrar-Glauber test (Green, 2008), autocorrelation of residuals by way of the Ljung-Box test (Gujarati, 2003), heteroskedasticity by way of the combined ARCH test with autocorrelation (Cipra, 2008)[1] and the normality of the distribution of the residual component by way of the multidimensional Doornik-Hansen test (Doornik, Hansen, 1994).

Data characteristics

The quantification of the specified partial equilibrium commodity model on the poultry meat market was based on data acquired from Situation and Forecast Reports – Poultry (2010) (Ministry of Agriculture of the Czech Republic, 1995–2012), from Annual Reports on the State of Agriculture (2010) (Institute of Agricultural Economics and Information, 1995–2012, General Information about Agriculture in the Czech Republic (2009)), and from the Statistics of Family Accounts (Czech Statistical Office, 1995–2012), for the period of years 1995–2011. In the conceived report, a classic econometric approach was utilized, the use of which enabled the portrayal of complicated relationships within the vertical and a relatively simple estimate of the intensity of relationships between the individual levels of the vertical. With the use of many restrictions based on the progressive testing of the composition of the model, a model characterizing the current situation and development in the poultry meat vertical in the Czech Republic was specified in gradual steps from the generally defined model of the food product chain (see e.g. Labys, 2003). In view of the nature of some of the variables, which are monitored only in time-aggregated annual values, the data base was necessarily restricted by this limitation and, for the estimate itself, time series data with a total number of 357 observations were used.

For the verification of one of the basic econometric assumptions of the absence of perfect multi-co-linearity, the Farrar-Glauber test was conducted on the underlying data, whereby the paired correlation matrix was quantified, and on the basis of the values of the correlation coefficients (*RCC*) the hypothesis on the absence of perfect multi-co-linearity was dismissed, as all $RCC < 0.7$.

For the verification of the econometric assumptions and the achievement of the required properties of the estimate, comprehensive tests of heteroskedasticity, the autocorrelation of residuals, and the normality of the distribution of the random component were further conducted for all equations. Quantified statistics are comprehensively set out in the conclusion of the estimate, where the achieved values are also interpreted. However, now, in advance, we can already state that

[1]ARCH test utilizes the principles of the Lagrange Multiplier test (Green, 2008), verifying the absence of group heteroskedasticity

the conducted tests confirmed the observance of the econometric assumptions of the linear model.

RESULTS AND DISCUSSION

As part of the specification, a nine-equation simultaneous model was drawn up, the following estimate of which was conducted, in accordance with the principle of limited information, by way of the two-step method of least squares. For this reason, attention is paid in the following interpretation successively to the results of the quantification of individual equations. The first explained variable in the system of equations is the quantity of the supply of poultry meat at the agricultural producer level, whereby the estimate of parameters of the explanatory variables is set out in Equation 1.

Equation 1: TSLS /source:own calculation/
Dependent variable: QSA
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

	coefficient	std. error	t-ratio	p-value	
const	110.264	41.7907	2.638	0.0083	***
PAP_1	-0.000990932	0.00146294	-0.6774	0.4982	
QDP	0.932329	0.0786116	11.86	1.91e-032	***
IM_ch	-0.765986	0.152425	-5.025	5.03e-07	***

Mean dependent var	277.8906	S.D. dependent var	36.56657
Sum squared resid	1111.544	S.E. of regression	9.624380
R-squared	0.944580	Adjusted R-squared	0.930725
F(3,12)	51.38214	P-value(F)	4.03e-07

It is evident from the outputs that while the demand of processors has a positive effect in accordance with the expectations, the quantity of import of chicken meat once again according to expectations has a negative effect, and surprisingly the same as the buyout price of the agricultural producer. In view of the very minimal unit effect of the farm price and primarily also in view of the non-proof of the statistical significance of the assessed variable, we can come to the conclusion that the buyout price is not a relevant determinant of the supply at the basic level of the vertical. The said interesting finding is also supported by statistical characteristics of the course of the supply and of the farm price, where, despite the fact that both are declining, the supply shows a multiply faster declining trend, whereby it partially shows its independence in regard to the buyout price. As has already been stated, the amount of demand has an adequate effect in a positive direction, whereby the unit change in the demand brings about a change of 0.93 unit *ceteris paribus* in the amount of supply and it can thus be indicated that the vertical could have the nature of a supply-driven chain. The quantity of imported chicken meat reduces the production supply *ceteris paribus* by approximately 0.76 unit, which corresponds to the current situation of increasing volumes of imported meat products and the slow replacements of domestic production with the said import. Similar results were also achieved, for example, by R a g u ž - D u r i ć el al. (2006);Z h a o et al.,(2000).

From a statistical viewpoint, it can be stated that the parameters of the explanatory variables with the exception of the delayed farm price are statistically significant at a selected level of significance ($\alpha = 0.01$) and the closeness of the dependence measured by way of an adjusted coefficient of determination is relatively very high ($R^2 = 0.93$), whereby the conclusiveness of the indicator was verified among all equations of the model by way of the standardized *F*-test.

A further explained variable at the producer level was the producer's buyout price, i.e. the farm price, where the effect of the import price and of the domestic processor price was anticipated, and for the option of the portrayal of the effect of inputs into production, the industrial feed producer price for the category of chicken broilers was also included. The conducted estimate of parameters is evidenced in Equation 2.

Equation 2: TSLS /source:own calculation/
Dependent variable: PAP
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

	coefficient	std. error	t-ratio	p-value	
const	3026.74	1710.72	1.769	0.0768	*
IPK	-0.0294816	0.0158574	-1.859	0.0630	*
PP	0.409148	0.0306154	13.36	9.80e-041	***
PP_f	0.448220	0.257558	1.740	0.0818	*

Mean dependent var	22253.56	S.D. dependent var	2298.927
Sum squared resid	3665670	S.E. of regression	552.6957
R-squared	0.953761	Adjusted R-squared	0.942201
F(3,12)	79.11967	P-value(F)	3.57e-08

The quantification of the parameters indicates, firstly, a very small (0.03 unit *ceteris paribus*) and negative effect of the import price of chicken meat, which means that the higher the import price, the more likely it is that it will be more difficult to actualize imported products on the domestic market, which could, as a final consequence, be accompanied by an increase in the production capacities and a slight decrease in the buyout price. Conversely, an increase of another explanatory variable – the processor price by a unit, would bring about an increase in the farm price by 0.4 unit (*ceteris paribus*), which can be interpreted as the anticipated movement based on a strong dependence of the producer on the purchaser and the existence of motivational expectations. The positive value of the parameter of the industrial feed producer price then indicates the logical necessity of increases in the buyout price along with increases in the prices of production inputs. However, in terms of intensity, it is evident that the unit increase of inputs would be accompanied by an increase of only 0.45 unit, *ceteris paribus*, which can once again lead to the conclusion that the price pressures on the production sphere are very intense.

In statistical terms, it can be stated that all of the parameters of the explanatory variables are statistically significant at a selected level of significance ($\alpha = 0.1$) and the closeness of the dependency measured by way of an adjusted coefficient of determination is relatively very high ($R^2 = 0.94$).

In the subsequent phase, an estimate of the parameters of the equations characterizing foreign trade in

poultry meat was conducted. Within Equation 3, the parameters of the import equation are estimated, and Equation 4 then sets out the estimate of the parameters of export.

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Equation 3: TSLS /source:own calculation/
Dependent variable: IM
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

             coefficient     std. error    t-ratio   p-value
  ------------------------------------------------------------
  const       55.5026        49.8525        1.113    0.2656
  IPK         -0.000958840    0.000479340  -2.000    0.0455   **
  DS           1.29145        0.306443      4.214    2.51e-05 ***
  QDC         -0.672454       0.329903     -2.038    0.0415   **

Mean dependent var   54.33125   S.D. dependent var   37.30450
Sum squared resid    3602.574   S.E. of regression   17.32670
R-squared            0.827416   Adjusted R-squared   0.784271
F(3,12)              22.11171   P-value(F)           0.000035
```

The conducted estimate did not achieve the anticipated values of the parameters that would have the effects within the quantified model in accordance with the materially logical verification, and even from a statistical viewpoint the results support the necessity of a deeper analysis and further work. A unit increase of the import price of chicken meat would likely slightly or in the short-term lower the competitiveness of foreign production and import would thus go down very slightly (by only 0.0009 unit). The decline is thus expressed by an almost negligible tempo, as the amount of imported products currently already significantly helps domestic production to cover the entire consumption. Further, in the model an increase in domestic slaughter of broilers is accompanied by an increase in import and, conversely, increases in domestic consumption would bring about a decline in import. The said illogical outputs are very likely caused by a reverse course of actual underlying values, which are undergoing significant shocks as a result of a sector crisis and entirely singular phenomena of declining numbers are occurring, but with growing domestic slaughter once again accompanied by a decline in overall production as well as consumption. In terms of economic interpretation, it is evident that a long-term increase in slaughter must be in the model accompanied by an increase in import. Similar conclusions can also be made in regard to the negative effect of consumption on import. The opposite result was achieved, for example, by Istudor et al. (2004) in simulations of the effects of the slaughter of hogs, and thus the analyzed dependence will be a further subject of deeper analysis in the related area of market simulations.

From a statistical viewpoint, it may be stated that all of the parameters (with the exception of the constant) of the explanatory variables are statistically significant at the selected level of significance ($\alpha = 0.05$) and, as has already been stated above, the closeness of dependence measured by way of an adjusted coefficient of determination ($R^2 = 0.78$) is at a relatively acceptable level, but, nevertheless, indicates the need for further modifications.

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Equation 4: TSLS /source:own calculation/
Dependent variable: EX
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

             coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const      -13.9711      5.40720      -2.584    0.0098    ***
  DV_3       -23.5651      5.44142      -4.331    1.49e-05  ***
  DS           0.296848    0.0224409    13.23     6.05e-040 ***

Mean dependent var   21.53189   S.D. dependent var   12.93527
Sum squared resid    172.4119   S.E. of regression   3.641765
R-squared            0.931305   Adjusted R-squared   0.920737
F(2,13)              88.12117   P-value(F)           2.75e-08
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In the export equation, the parameter of the dummy variable was quantified, which comprised the ratio of the import price and export price of chicken meat. It is evident from the resulting value that an increase in the said ratio by a unit will bring about a decrease in export of approximately 23 units, *ceteris paribus*, i.e. a higher value of the import price as compared to the export price should predicate a decline in the export of poultry meat. In view of the fact that the value of the import price is in reality falling and the export price is stagnating, then the above-mentioned ratio is declining in time and thus the negative sign of the parameter then corresponds to a slight increase in export, which can be considered a plausible outcome of the economic principles of foreign trade based on comparing the price level. Similarly also, for example, K u h n (2004). The positive value of the parameter of domestic slaughter supports the possibility of a practical increase in export with growing volumes of domestic slaughter, with an intensity of change in export of approximately 0.3 unit upon a unit change in slaughter, *ceteris paribus*.

A statistical assessment evidences that both commented explanatory variables are statistically significant at the selected level of significance ($\alpha = 0.01$). The closeness of dependence measured by way of an adjusted coefficient of determination is still at a very high value ($R^2 = 0.92$).

The following Equation 5 contains the estimated parameters of the equation explaining the demand for meat on the processor level.

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Equation 5: TSLS /source:own calculation/
Dependent variable: QDP
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

             coefficient   std. error   t-ratio    p-value
  ------------------------------------------------------------
  const      -82.4690      18.6628      -4.419    9.92e-06  ***
  IM_ch       -0.347574     0.126456    -2.749    0.0060    ***
  QDC          1.03608      0.0676171   15.32     5.39e-053 ***

Mean dependent var   229.4973   S.D. dependent var   42.08579
Sum squared resid    841.9316   S.E. of regression   8.047606
R-squared            0.968311   Adjusted R-squared   0.963435
F(2,13)              175.4006   P-value(F)           3.94e-10
```

The achieved values of the parameters correspond, in terms of economic verification, to the assumptions, as the amount of imported chicken meat would, with a constant or in real terms declining domestic consumption, create pressure on domestic producers, who would be forced to react by lowering domestic production (a unit increase in import predicates a decrease in

demand of 0.35 unit, *ceteris paribus*). On the other hand, a unit increase in the consumer demand would be accompanied by a fully adequate (proportional) change in the demand by processors. From a statistical viewpoint, the closeness of dependence in the said function is at a high level ($R^2 = 0.2$) and all parameters are statistically significant ($\alpha = 0.01$).

At the processor level, an equation portraying the effects of the determinants of the industrial producer price, i.e. the processor price, was also conceived, see Equation 6.

Equation 6: TSLS /source:own calculation/
Dependent variable: PP
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

	coefficient	std. error	t-ratio	p-value	
const	6843.78	2918.84	2.345	0.0190	**
DV_3	1911.87	1072.64	1.782	0.0747	*
CP	0.735003	0.0416621	17.64	1.17e-069	***
T	-697.439	38.9542	-17.90	1.10e-071	***

Mean dependent var	42416.41	S.D. dependent var	5364.907
Sum squared resid	5712926	S.E. of regression	689.9835
R-squared	0.986767	Adjusted R-squared	0.983459
F(3,12)	283.4250	P-value(F)	2.12e-11

The interpretation of the quantified parameters corresponds to the economic assumptions. The consumer price relatively very strongly motivates the explained variable, as a unit increase in the consumer price increases the processor price by 0.73 unit, *ceteris paribus*. In view of the processes of price transmission, the said fact can be expected, but nevertheless indicates that an increase in the processor price would be lower than the original impulse, which is likely the result of very strong competitive pressures on the processor level of the vertical. The analyzed variable is also closely affected by foreign trade prices, the ratio of which is the content of the utilized dummy variable, and which has a positive and very strong effect on the processor price level. A unit increase of the dummy is accompanied by an increase of the industrial price by approximately 1912 units, i.e. the higher the import price in relation to the export price of chicken meat, the more likely it is that import will be less competitive and a space is thus opened up for an increase in domestic production accompanied by a decline in prices as a result of pressure from the consumer level. The last included variable was the time vector, the negative parameter of which evidences long-term slightly declining values of the processor price. Statistical verification evidences that all of the parameters of the explanatory variables are statistically significant at the selected level of significance ($\alpha = 0.1$) and the closeness of dependence measured by way of an adjusted coefficient of determination once again increased to a relatively very high level ($R^2 = 0.98$).

In the second to last stochastic equation of the specified commodity model, the consumer demand for poultry meat is explained, which is dependent on the average consumer price of poultry meat, as well as on the prices of beef as well as pork meat – see Equation 7.

Equation 7: TSLS /source:own calculation/
Dependent variable: QDC
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

	coefficient	std. error	t-ratio	p-value	
const	35.3406	183.693	0.1924	0.8474	
CP_b	0.00432332	0.00102221	4.229	2.34e-05	***
CP	-0.00643560	0.00189235	-3.401	0.0007	***
CP_p	0.00130988	0.00143487	0.9129	0.3613	

Mean dependent var	311.6844	S.D. dependent var	45.88997
Sum squared resid	7815.792	S.E. of regression	25.52089
R-squared	0.752574	Adjusted R-squared	0.690717
F(3,12)	11.86077	P-value(F)	0.000668

The provided outputs of the estimate indicate correlations between the individual types of meat and, further, they partially confirm the economic assumptions, as increases in the price of poultry meat by a unit would bring about a very slight decline in the actual consumption. Further, the result documents the slightly competitive relationships between poultry meat and beef/pork meats, as their unit increase brings about an increase, albeit negligible in terms of value (0.004 or 0.001 unit). Here, however, the statistical significance of the effect of pork meat was unfortunately not confirmed, and thus the effect will further be abstracted away from. Similar links were achieved, for example, by B r u c k n e r et al. (2013), whereby the outputs of the research show that all types of meat can be mutually substituted and the reactions of consumers confirm that. From a statistical viewpoint, it can be stated that the parameters of the explanatory variables with the exception of the consumer price of pork meat are statistically significant at the selected level of significance ($\alpha = 0.01$) and the closeness of dependence measured by way of an adjusted coefficient of determination is acceptable ($R^2 = 0.69$).

The last stochastic equation of the model is focused on modelling the consumer price, which is explained by the processor price, by the consumer price of beef meat, and by the dummy variable, which comprises the ratio of the import price and the export price of chicken meat, see Equation 8.

Equation 8: TSLS /source:own calculation/
Dependent variable: CP
Instruments: const PAP_1 IM_ch IPK PP_f DS DV_3 T CP_b CP_p

	coefficient	std. error	t-ratio	p-value	
const	-30515.2	7557.65	-4.038	5.40e-05	***
PP	1.00458	0.0725220	13.85	1.24e-043	***
CP_b	0.412997	0.0446156	9.257	2.11e-020	***
DV_3	-5278.72	1731.70	-3.048	0.0023	***

Mean dependent var	54892.19	S.D. dependent var	5075.152
Sum squared resid	16147447	S.E. of regression	1160.009
R-squared	0.958206	Adjusted R-squared	0.947757
F(3,12)	83.68097	P-value(F)	2.59e-08

In terms of the achieved outputs, it can be stated that a unit increase in the processor price would, *ceteris paribus*, increase the consumer price by 1.005 unit, whereby the ascertained direction as well as intensity correspond to the assumptions. The consumer price of beef meat has a positive effect (a unit increase in the price of beef meat would bring about a decrease in the price of poultry meat at the consumer level of 0.41 unit, *ceteris paribus*), and thus

we can tend to assume a complementary relationship of both types of meat. A unit increase of the dummy consisting of the ration of the import price and the export price of chicken meat, under the condition of *ceteris paribus*, predicate a decrease in the consumer price of poultry meat by approximately 5279 units. An increase in the import price as compared to the export price would likely create space for domestic production and a decrease in its price.

Statistical verification evidences that all parameters of the explanatory variables are statistically significant at the selected level of significance ($\alpha = 0.01$) and the closeness of dependence measured by way of an adjusted coefficient of determination once again increased to a relatively very high level ($R^2 = 0.95$).

For a comprehensive recapitulation of the quantified relationships, it is appropriate to record the resulting form of the estimated simultaneous commodity model for poultry meat in the Czech Republic by way of an equational notation (as the model was intended for the portrayal of equilibrium, a necessary part of it is a balance identity):

$$Q_{SA,PLM,t} = \underset{(41.79)}{110.26} - \underset{(0.0015)}{0.00099}PAP_{PLM,t-1} + \underset{(0.0786)}{0.93}Q_{DP,PLM,t} - \underset{(0.15)}{0.766}Q_{IM,CHM,t}$$

$$PAP_{PLM,t} = \underset{(1710.7)}{3026.7} - \underset{(0.16)}{0.03}IPK_{PLM,t} + \underset{(0.03)}{0.4}PP_{PLM,t} + \underset{(0.26)}{0.4}PP_{f,t}$$

$$Q_{IM,PLM,t} = \underset{(49.85)}{55.5} - \underset{(0.00048)}{0.00096}IPK_{PLM,t} + \underset{(0.3)}{1.3}DS_{PLM,t} - \underset{(0.33)}{0.67}Q_{DC,PLM,t}$$

$$Q_{EX,PLM,t} = \underset{(5.4)}{-13.97} - \underset{(5.44)}{23.57}DV3 + \underset{(0.02)}{0.297}DS_{PLM,t}$$

$$Q_{DP,PLM,t} = \underset{(18.66)}{-82.47} - \underset{(0.1)}{0.35}Q_{IM,CHM,t} + \underset{(0.06)}{1.03}Q_{DC,PLM,t}$$

$$PP_{PLM,t} = \underset{(2918.8)}{6843.78} + \underset{(1072.6)}{1911.87}DV3 + \underset{(0.04)}{0.735}CP_{PLM,t} - \underset{(38.9)}{697.4}T$$

$$Q_{DC,PLM,t} = \underset{(183.7)}{35.34} + \underset{(0.001)}{0.004}CP_{BM,t} - \underset{(0.002)}{0.006}CP_{PLM,t} + \underset{(0.001)}{0.001}CP_{PM,t}$$

$$CP_{PLM,t} = \underset{(7557.7)}{-30515.2} + \underset{(0.07)}{1.005}PP_{PLM,t} + \underset{(0.04)}{0.41}CP_{BM,t} - \underset{(1731.7)}{5278.72}DV3$$

$$Q_{IM,PM,t} + Q_{SP,PM,t} = Q_{DC,PM,t} + Q_{EX,PM,t}$$

In the introduction to the conducted analysis of estimated correlations, a reference to comprehensive testing of the econometric assumptions of the created model was mentioned, the results of which are set out in Tables 1–3. For the verification of the normal distribution of random components, the multi-criteria Doornik-Hansen test was chosen (Table 1), the achieved *P*-value of which documents the confirmation of the zero hypothesis of the normal distribution of residuals in the conceived equations.

Verification of the absence of autocorrelation of residuals was conducted by way of the Ljung-Box test, the simplified summary of which for all of the stochastic equations of the specified model is set out – see Table 2.

On the basis of a comparison of the achieved *P*-values with the critical value of the LB test, it may be stated that the model is free of autocorrelation of residuals.

Table 1. Test for multivariate normality of residuals

Doornik, Hansen	Chi-Square (20) = 20.5846	With *P*-value = 0.195037

Source: own calculations

Table 2. Ljung-Box test (critical value = 0.05)

Equation 1:
Ljung-Box Q' : Chi-Square (1) = 0.00307294 [0.9558]
Equation 2:
Ljung-Box Q' : Chi-Square (1) = 0.946285 [0.3307]
Equation 3:
Ljung-Box Q' : Chi-Square (1) = 1.72585 [0.1889]
Equation 4:
Ljung-Box Q' : Chi-Square (1) = 0.0211265 [0.8844]
Equation 5:
Ljung-Box Q' : Chi-Square (1) = 0.995479 [0.3184]
Equation 6:
Ljung-Box Q' : Chi-Square (1) = 0.0331584 [0.8555]
Equation 7:
Ljung-Box Q': Chi-Square (1) = 0.0367521 [0.8480]
Equation 8:
Ljung-Box Q': Chi-Square (1) = 0.237356 [0.6261]

Source: own calculations

In conclusion, heteroskedasticity was also tested, by way of the combined ARCH test. Because autocorrelation of residuals was already ruled out by way of the previous LB test, the applied combined test can also be utilized for verification, by way of which the hypothesis of homoskedasticity is subsequently conclusively confirmed or disproved (Table 3).

It is evident from the outputs that the zero hypothesis of homoskedasticity cannot be dismissed for any of the tested equations, which confirms the observance of the basic econometric assumptions of the conceived model.

CONCLUSION

The analyzed poultry meat market underwent significant changes within the analyzed period, which were determined by the economic development of a small open economy as well as by several significant shocks that significantly affected both the structure of the market and mutual interactions within the vertical, and also reactions of the involved entities to external impulses. In the comprehensive assessment of the overall development of the basic levels of the monitored vertical, it is necessary to state that the overall supply at the agricultural producer level declined by more than 25%, poultry numbers in the battening category first showed a massive increase, but subsequently also a

Table 3. ARCH test (critical value = 0.05)

Equation 1:
Test statistic: LM = 0.0778082
With *P*-value = P(Chi-Square (1) > 0.0778082) = 0.78029
Equation 2:
Test statistic: LM = 0.991824
With *P*-value = P(Chi-Square (1) > 0.991824) = 0.319297
Equation 3:
Test statistic: LM = 3.70967
With *P*-value = P(Chi-Square (1) > 3.70967) = 0.054098
Equation 4:
Test statistic: LM = 0.183193
With *P*-value = P(Chi-Square (1) > 0.183193) = 0.668643
Equation 5:
Test statistic: LM = 2.64345
With *P*-value = P(Chi-Square (1) > 2.64345) = 0.103978
Equation 6:
Test statistic: LM = 0.0221313
With p-value = P(Chi-Square (1) > 0.0221313) = 0.881738
Equation 7:
Test statistic: LM = 0.539409
With *P*-value = P(Chi-Square (1) > 0.539409) = 0.462678
Equation 8:
Test statistic: LM = 0.332181
With *P*-value = P(Chi-Square (1) > 0.332181) = 0.564377

Source: own calculations

significant decline, and thus they increased overall by approximately 33%, whereby changes in the volume of domestic slaughter also occurred, which actually increased overall in the course of the monitored period by 167%. Negative development was seen in the farm price, which decreased in the course of the monitored period by 9.4%, which is, when compared to the growing trend of production input prices, an alarming indicator. When compared to the decline in the processor price (3.9%) and the increase in the consumer price (16%)[2], the development of price growth is considerably non-proportional and we can see tremendous pressure primarily on the production level of the vertical, thanks to which the development of the consumer price is likely still perceived by end customers as reasonable.

[2] in assessing the development of the consumer price, it is necessary to realize that this is a weighted price comprising the prices of individual meat products, whereby in terms of volume representation, the greatest share is held by products with a lower increase, i.e. in assessing the development of the price of actual fresh meat at the consumer level, the increase in price would likely be much higher

In terms of the further basic characteristics, it can be stated that within the monitored period there was a sharp increase in import of 1900% with a simultaneous decrease in the import price by approximately 25%, an increase in export of 1200%, but with an increase in the export price of only 0.4%. Several partial conclusions can be conceived from the above. The decline in supply does not correspond to the increase in the numbers of poultry, which is apparently caused by increased export and, at the same time, also by a significant increase in import, which balances out the forced stoppages of Czech farmers, whose buyout prices are pushed down to such a low level that for a number of entities production is no longer profitable and a significant decrease of numbers is occurring. Additionally, for the Czech consumer, a partially positive piece of information is the fact that the balancing out of fluctuations in the production base is brought about by import with the simultaneous decreasing of the import price, which subsequently must necessarily determine the subsequent segments in the vertical. Last but not least, it can also be stated that increasing end prices are not the result of increases in prices at the production level, which, on the contrary, are declining, including processor prices, and thus all increases in output prices are fully under the responsibility of the last (commercial) segments of the vertical.

In analyzing the outputs of the conceived commodity model, some facts set out in the previous sections of the conclusions are confirmed, and some partial results then provide support for further interpretations of connections within the analyzed vertical.

The model confirmed the declining tendency of the farm supply, which, however, lacks the necessary sensitivity in regard to the basic determinant in the form of the buyout price. In terms of the significant determinants, the agricultural supply is pulled by the volume demand of the processing sector under the current, very strong influence of foreign trade. The agricultural producer price is sensitive to fluctuations in processor prices, but also to those of prices of the basic factors of production, which are actually a stronger factor by way of their intensity. The effect of foreign trade prices is also seen here, which apparently have a certain position through purchasers (processors), which is also further evidenced by the positive effect of the processor price on the buyout price.

Significant increases in the volumes of import as well as export are modified both by the development of the ratio between the domestic and foreign price, as well as by the development of domestic consumption and domestic slaughter, which is confirmed by outputs of the estimated model. In the export equation, standard economic principles were proven, which increase export while increasing the ration of the import and export price. In the import equation, the anticipated relationships were not proven, and it will be necessary to modify the system for applicable

portrayal. According to the outputs of the model, the overall domestic demand of the processing sector is strongly pulled primarily by the volume of the linked consumer segment of the chain and, at the same time, is decreased by the implemented import. The processor price is proportionally pulled by the consumer price and, at the same time, very intensely by foreign trade prices, primarily by the price of import. The domestic consumption function has the anticipated development, as an increase in the consumer price would bring about a minimum decrease in the demand, which evidences the nature of a basic good among food products. In terms of the consumer price, we see statistically significant effects of the processor price, of the price of beef meat, and of the foreign trade prices, whereby the industrial producer price increases the consumer price.

Overall, it may be stated that the estimated model does a very good job of reflecting the principles of the analyzed vertical as analyzed above, declares the selected determinants of the development of the supply of as well as the demand for poultry meat, as well as the basic connections between the individual levels of the poultry meat vertical, and thus it can be considered an appropriate tool for the subsequent analysis of the poultry meat market and the resultant simulation calculations.

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