Data are obtained from Czech Statistical Office (CZSO, 2020). Time series of monthly data for years 2010-2019 are used. Variables and their descriptive statistics are summarized in Table 1.

Table 1 – Variables and descriptive statistics.

Variable	**Description**	**Mean**	**Std.dev.**	**Min**	**Max**
y_1	Prasata jatečná v živém (CZV) (Kč/kg)	30.55	3.08	25.45	36.95
y_2	Vepřová kýta bez kosti (CZP) (Kč/kg)	77.61	5.83	69.16	100.32
y_3	Vepřová kýta bez kosti (SC) (Kč/kg)	116.9	9.54	100.7	150
x_1	Index cen zemědělských výrobců - živočišná výroba (báze 2010)	112.25	7.78	96.2	126.2
x_2	Index cen průmyslových výrobců (báze 2005)	100.62	2.85	94.3	105
x_3	Index cen průmyslových výrobců - ceny energie (báze 2005)	101.56	4.78	94.7	110.8
x_4	Index stavební produkce (údaj očištěný o pracovní dny) (báze 2015)	99.81	26.66	43.13	143.79
x_5	Indexy spotřebitelských cen podle klasifikace COICOP - měsíční (báze 2015)	100.22	4.36	92.5	109.4
x_6	Průměrná měsíční mzda (Kč) (čtvrtletně)	27427.5	3464.2	22738	36161
x_7	Směnný kurz CZK/EUR	26.05	1	24.27	27.9
x_8	Produkce vepřového masa v tis. tun v EU-27 (bez UK)	1842	110.02	1644.1	2343.2
x_9	Ceny chovných selat ž.hm. (Kč/kg)	56.37	5.39	46.15	67.77

At the first stage, elasticities are calculated by employing log-log model in following form (Model 1):

$$lny_i \ = \beta_{0j} + \beta_{1j} lnx_j \ + \varepsilon \qquad (1)$$

Where y_i - endogenous variables; x_j - exogenous variables; β_0 and β_1 - regression coefficients; ε – residuals; $i \in (1;3)$ – denotes number of endogenous variable; $j \in (1;7)$ – denotes number of exogenous variable.

Model specification allows to estimate endogenous variable elasticity, which is equal to regression coefficient β_1. In other words, regression coefficient β_1 represents change in endogenous variable y_i when exogenous variable changes by 1%.

At the second stage, we estimate the following log-log model (Model 2):

$$lny_i \ = \beta_{0j} + \beta_{1j} lnx_j \ + \beta_{2k} lnx_k \ + \varepsilon \qquad (2)$$

Where y_i - endogenous variables; x_j , x_k - exogenous variables; $\beta_0, \beta_1, \beta_2$ - regression coefficients; ε – residuals; $i \in (1;3)$ – denotes number of endogenous variable; $j \in (1;6), k \in (2;7)$ – denotes number of exogenous variable.

Regression coefficients β_1 and β_2 represents percentage change of endogenous variable when both exogenous variables x_j and x_k change by 1%.

Results of linear regression models estimation for the first stage of analysis (Model 1) are represented in Tables 2,3 and 4.

Table 2 – Coefficient β_{1j} for Model 1.

	lny_1	lny_2	lny_3
lnx_1	**0.877302*** **	**0.658822*** **	**0.658429*** **
lnx_2	**2.08792*** **	**1.57298*** **	**1.48842*** **
lnx_3	**0.864507*** **	**0.747336*** **	0.179947
lnx_4	0.052368	0.052368	0.008181
lnx_5	**0.668499*** **	**0.669755*** **	**1.73223*** **
lnx_6	0.054581	0.054504	**0.497291*** **
lnx_7	**0.43809**	**0.675697*** **	**0.765427*** **

Note: *** - $p < 0.01$

Table 3 – Coefficient β_{0j} for Model 1.

	lny_1	lny_2	lny_3
lnx_1	-0.70995	**1.24921*** **	**1.63337*** **
lnx_2	**-6.209*** **	**-2.89814*** **	-2.09875
lnx_3	-0.57648	0.901241	**3.93367*** **
lnx_4	**3.18176*** **	**3.18176*** **	**4.72832*** **
lnx_5	0.33852	1.26877	**-3.2196*** **
lnx_6	**2.85702*** **	**3.79243*** **	-0.32021
lnx_7	1.98652	**2.14672*** **	**2.26324*** **

Note: *** - $p < 0.01$

Table 4 – R^2 for Model 1.

	lny_1	lny_2	lny_3
lnx_1	0.472	0.65	0.491
lnx_2	0.328	0.296	0.22
lnx_3	0.172	0.204	0.01
lnx_4	0.025	0.025	0.001
lnx_5	0.09	0.143	**0.796**
lnx_6	0.004	0.008	0.549
lnx_7	0.028	0.123	0.129

Durbin-Watson test shows autocorrelation in residuals, therefore the model specifications should be changed. To address the autocorrelation in residuals, we specify the model in autoregressive distributed lag form $ADL(m,n)$:

$$lny_{ti} = \alpha_{0i} + \sum_{k=1}^{m} \alpha_k lny_{(t-k)i} + \sum_{p=0}^{n} \beta_p lnx_{(t-p)j} + \varepsilon_t \qquad (1)$$

where y_i - endogenous variables; x_j - exogenous variables; α_k and β_p - regression coefficients; α_{0i} – constant; ε_t – residuals; k and p - number of lags for endogenous and exogenous variables; m and n – maximum lag of endogenous and exogenous variables; $i \in (1;3)$ – denotes number of endogenous variable; $j \in (1;7)$ – denotes number of exogenous variable.

Selection of maximum lag has been done for each endogenous and exogenous variable based on Akaike (AIC), Schwarz Bayesian (BIC) and Hannan-Quinn (HQC) information criteria.

Table 2 – Maximum lag selection for endogenous and exogenous variables.

Variable	**Maximum lag as per:**			$\boldsymbol{m}$	$\boldsymbol{n}$
	AIC	**BIC**	**HQC**		
y_1	11	5	5	**5**	-
y_2	2	2	2	**2**	-
y_3	2	1	1	**1**	-
x_1	12	2	12	-	**12**
x_2	2	2	2	-	**2**
x_3	1	1	1	-	**1**
x_4	15	15	15	-	**15**
x_5	1	1	1	-	**1**
x_6	16	16	16	-	**16**
x_7	4	2	4	-	**4**

Model specification has been corrected after estimating the model in general form by excluding the variables with higher p-value (under assumption of alpha-level of 0.99). Results of ADL model estimation are shown in Table 3, Table 4, Table 5.

Table 3 – ADL(m,n) model estimation for variable y1, *** - p-value < 0.01. Source: own calculations.

Variable	*Coefficient*	*Std. Error*	*t-ratio*
const	-2.093***	0.572	-3.657
l_y1_1	1.457***	0.073	20.08
l_y1_2	-0.642***	0.066	-9.662

l_x1_12	-0.185***	0.042	-4.417
l_x3_1	0.357***	0.067	5.331
l_x7_4	0.355***	0.087	4.057
l_x8_21	0.106***	0.038	2.819
R-squared	0.963		
F(5, 90)	401.9378***		
Durbin-Watson	1.647		

Results of the model estimation for dependent variable y_1 shows several specific features. Variable y_1 represents monthly price of pigs for slaughter, and there is significant autocorrelation relationship between prices in current period and prices in 2 previous periods. While this is not surprising for time series of prices, values of coefficients suggest interesting conclusions. A 1% increase in prices in previous months will lead to 1.46% increase of producer prices in current month, while 1% increase in prices 2 months ago will lead to a decrease of 0.64% in current month. This can be explained by change in demand as prices rise for more than 1 month, forcing producers to decrease prices to still be able to maintain the quantities of supply on acceptable for them level. Comparison with estimations for variables y_2 (industrial producers' pork prices) and y_3 (consumer pork prices) shows, that these two variables have statistically significant relationship with lag 1 variables, in other words with values only in previous month, and for both time series the impact is positive, suggesting increase in current month prices if there was increase in prices in previous month. Taking this into consideration, livestock producers are operating in the market with higher price elasticity of demand, i.e. demand from wholesale buyers of pigs.

Constant has negative value but taking into consideration the log-log form of the estimated model, the interpretation of constant term is that the portion of producer price of pigs that is not under influence of other independent variables is $e^{-2.093}$ = 0.12 CZK.

Statistically significant influence on producer prices of pigs has been confirmed from variables x_1 (Agricultural producers prices index – livestock production), x_3 (Industrial producers prices – energy prices index) and x_7 (Exchange rate CZK/EUR). There are two important points in these relationships. Firstly, price of pigs reacts to changes in agricultural producers' prices index with a lag of 12 months, and estimations show that 1% increase in producers' prices index leads to only 0.18% decrease of prices of pigs.

Secondly, big magnitude of impact comes from the exchange rate CZK/EUR, as 1% increase of exchange rate (depreciation of domestic currency) would lead to 0.35% increase in prices of pigs. This impact is the same to that from Industrial producers' energy prices index (0.35%). Pigs prices' dependence on currency exchange rate can be an evidence of the significant part of producer's costs is in foreign currency, therefore any significant increase of exchange rate should be compensated by increase in selling price. Lag between change in exchange price and change in pigs' price is 4 months. The length of this period might show the level of flexibility in prices for producers of pigs, as there is no immediate reaction on changes in currency exchange rates. At the same time, as the currency exchange rate elasticity of prices of pigs is lower than 1, portion of exchange rate change is not transmitted to producer prices of pigs and is absorbed by producers as cost.

The impact of energy prices index (x_3) is the same as for exchange rate impact. A 1% changes in energy prices index leads to 0.35% change in producer prices of pigs, while lag is equal to 1, which means that changes in energy prices index in previous period are reflected in producer price in current period. Interestingly, livestock prices index elasticity (x_1) has negative value (-0.18) but with relatively long lag of 12 months. It suggests corrective influence on current prices from prices same months one year ago. Under the assumption of perfect competition on the market, wholesale buyers of pigs (industrial processors of pork) expect in average 0.18% decrease in current year prices if livestock prices (in general for livestock products, not only pork) have been risen by 1% in the same month last year. This corrective relationship might suggest that supply of pigs for slaughter on the market is relatively flexible – increase in prices in last year will incentivize producers to increase supply in current year, which will negatively affect prices.

Prices of pigs for slaughter and production of pork meat in EU27 (variable x_8) have quite lagged relationship, as only changes of production 21 months ago have statistically significant impact on prices in current period. At the same time, the coefficient is positive (1% change in production 21 months ago would lead to 0.1% increase in prices of pigs for slaughter), which is counterintuitive from microeconomic perspective.

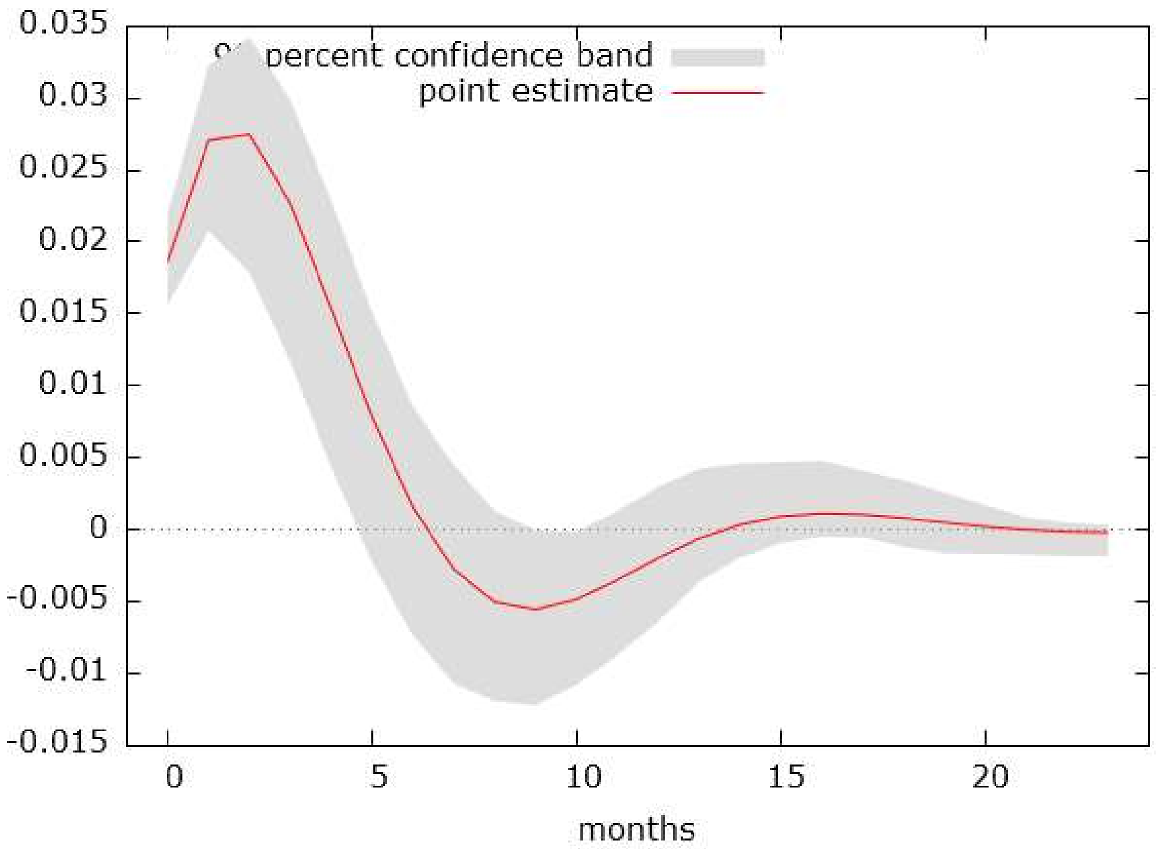

Diagram 1 – Impulse response of lny_1 to a shock in lny_1 with confidence interval 0.99. Source: own calculations.

Diagram 1 shows the impulse response of variable y_1 to a one-standard error shock in the same variable. Response of producer prices of pigs is the most in first 2-3 months after the shock, but about 12 to 15 months are needed for prices to return to the previous level.

Table 4 – ADL(m,n) model estimation for variable y2, *** - p-value < 0.01, ** - p-value < 0.05. Source: own calculations.

Variable	*Coefficient*	*Std. Error*	*t-ratio*
const	-2.155***	0.512	-4.208
l_y2_1	1.023***	0.041	24.74
l_x1	0.483***	0.12	4.015
l_x1_1	-0.636***	0.112	-5.638
l_x2	0.446***	0.107	4.174
l_x8_3	0.096**	0.037	2.569
R-squared	0.921		
F(4, 90)	259.7045***		
Durbin-Watson	1.479		

Results for dependent variable y_2 (producer prices of pork) presented on the Table 4 shows negative constant of -2.155. The log-log specification of the model suggests that constant portion of producers' prices of pork is equal to $e^{-2.155}$ = 0.12 CZK, which is equal to producer prices of pigs. Taking this estimation together with model for producer prices of pigs shows that there is no constant portion of producers' prices of pork that can be attributed to costs of industrial processors of pork.

Modelling shows, that 1% change in producer prices of pork in previous period leads to 1.023% change in current period. There is an increasing response to increase in prices, as can be also seen on impulse response diagram (Diagram 2).

Producer prices of pork have positive connection with livestock prices index (x_1) in current month and negative connection in previous month. Thus, 1% increase of livestock prices index in previous month will lead to 0.64% decrease of producer prices of pork in current month, while 1% increase of livestock prices index in current month will lead to 0.48% increase in producer prices of pork in current month. There is also a positive connection between industrial producers' index (x_2) and producer prices of pork, however the magnitude of the influence is not big (0.44% increase in pork price if there is 1% increase of industrial producers' index in the same period) and lower than for livestock prices index.

Coefficient for variable x_8 (production of pork meat in EU27) with lag 3 is statistically significant at α-level 0.95. Value of the coefficient suggest that 1% increase in pork production in EU27 countries 3 months ago would lead to 0.1% increase in producer prices of pork in current period in Czech Republic.

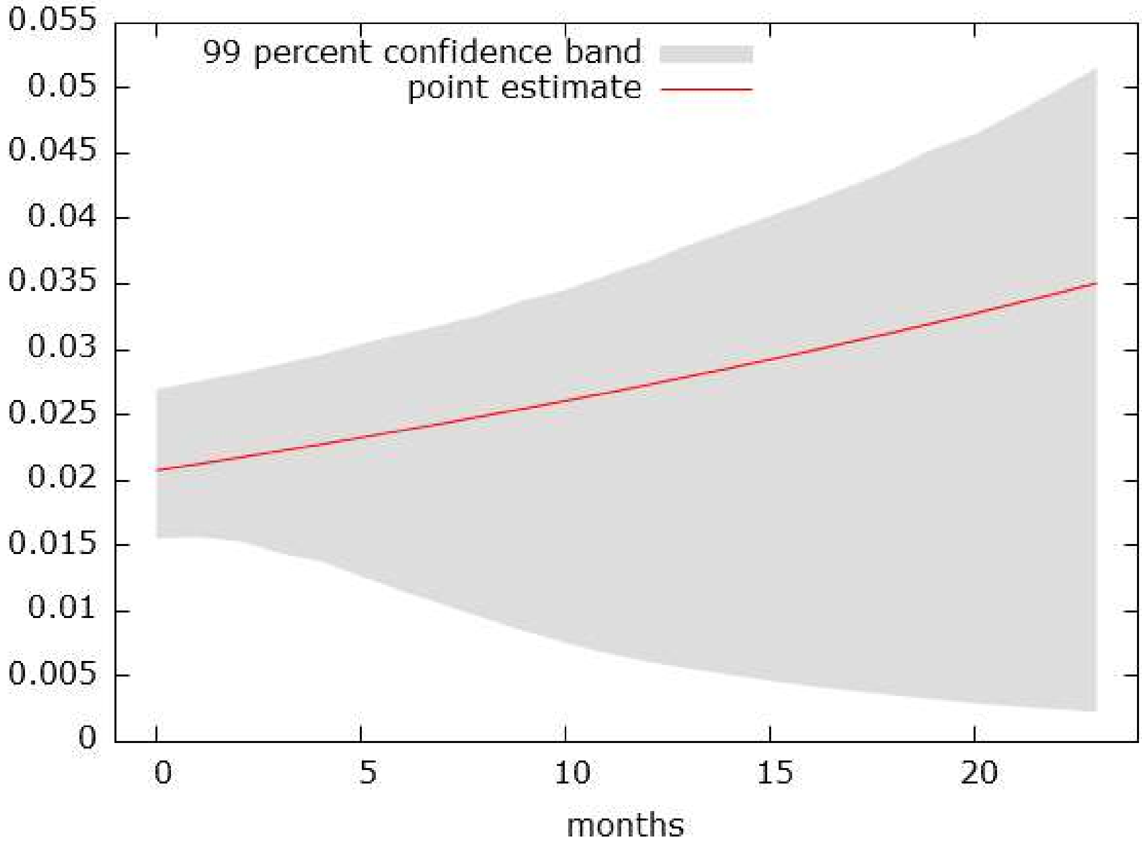

Diagram 2 – Impulse response of lny_2 to a shock in lny_2 with confidence interval 0.99. Source: own calculations

Diagram 2 shows the impulse response of variable y_2 to a one-standard error shock in the same variable. The line of response of wholesale prices of pork is convex and increasing. Interestingly, the line of response is not converging to the initial value of the variable.

Table 5 – ADL(m,n) model estimation for variable y3, *** - p-value < 0.01, * - p-value < 0.1. Source: own calculations.

Variable	***Coefficient***	***Std. Error***	***t-ratio***
const	-0.884**	0.361	-2.448
l_y3_1	0.93***	0.03	30.48
l_x4	-0.021**	0.009	-2.107
l_x4_1	0.048***	0.01	4.479
L_x8_16	0.146***	0.046	3.194
R-squared	0.90		
F(3, 119)	259.4175***		

Durbin-Watson	2.295		

ADL model estimation for dependent variable y_3 (consumer prices of pork) shows that constant term is statistically significant on the confidence interval 0.95. There is statistically significant coefficient for lag 1, showing that 1% change in consumer prices of pork in previous month will lead to 0.93% change in consumer prices of pork in current month.

Most interesting result of model for consumer prices of pork is statistically significant coefficient for independent variable x_4 (construction output index), however magnitude of these influences is relatively small. Results suggest, that 1% increase in construction output index in previous month will result in 0.05% increase in consumer prices of pork, as well as 1% increase in construction output index in current month will result in 0.02% decrease in consumer prices of pork in the same month (at the same time, this coefficient is only significant on higher α-level of 0.95). The connection between construction output index can be described taking into consideration the nature of the both indicators. Simply logic suggests, that increase in construction output relates to economy growth, which is often coincides with increase in incomes and consumer prices. Therefore, economic growth increases disposable incomes of households, which lead to increase of demand for food (up until saturation point) and increase demand for housing. Another important consideration here is the monetary policy of central bank. Expansionary monetary policy of central bank, characterized by low interest rates, increases inflation risk and demand for housing at the same time. It is important to mention, that monetary policy of Czech National Bank can be characterized as expansionary in the period of 2010-2019, therefore it would be expected to see a statistically significant connection between consumer prices (including pork prices) and construction output index.

Coefficient for variable x_8 (production of pork meat in EU27) with lag 16 is statistically significant and is equal to 0.146, meaning that 1% increase in production of pork meat in EU27 countries 16 months ago would cause 0.15% increase in consumer prices of pork in Czech Republic in current period. As it might seem counterintuitive from microeconomic perspective, this relationship might suggest lower level of integration between pork meat markets of Czech Republic and European Union. Interestingly, coefficient for production of pork meat in EU27 is positive in models for all three dependent variables (y_1, y_2, y_3), but the lag differs from 3 months (for producer prices of pork) to 16 months (for consumer prices of pork) to 21 months (price of pigs for slaughter). Shortest lag is for producer prices of pork, which might suggest that this step of supply chain is the mostly connected with EU pork meat market outside Czech Republic, that allows them to reach at the highest pace to the changes in European production of pork.

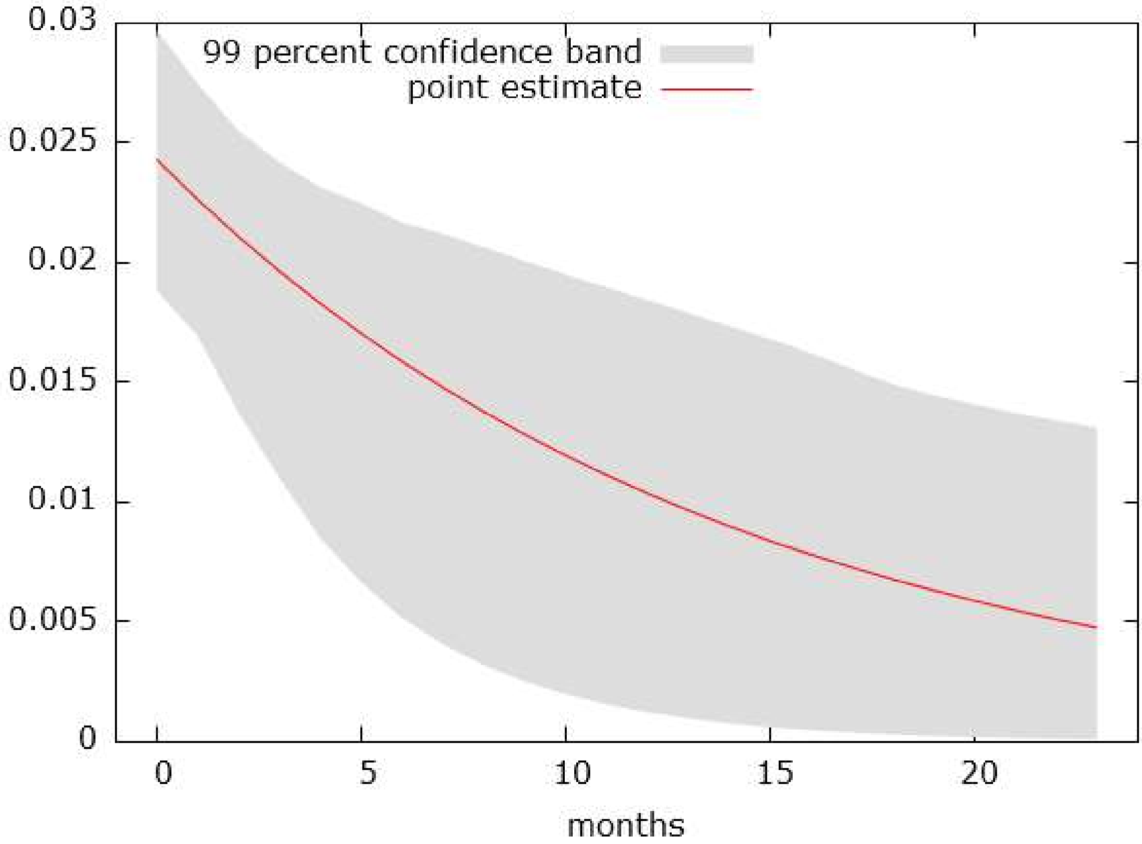

Diagram 3 – Impulse response of lny_3 to a shock in lny_3 with confidence interval 0.99. Source: own calculations

Diagram 3 shows the impulse response of variable y_3 to a one-standard error shock in the same variable. The line of response of wholesale prices of pork is convex, and unlike variable y_2 it converges back to the equilibrium, but it takes more than 15 months for the price to return to previous level.

Ceny chovných selat ž.hm. (Kč/kg) - forecast

For the purposes of forecasting, we use monthly prices of breeding piglets for the period of 2010.01 – 2020.04 and fit AR-model in the following classical form:

$$lnx_{9t} = \alpha_{09} + \sum_{k=1}^{m} \alpha_k lnx_{9(t-k)} + \varepsilon_t \qquad (1)$$

where x_9 - endogenous variable; α_k - regression coefficients; α_{0i} – constant; ε_t – residuals; k - number of lags; m – maximum lag; i – denotes number of endogenous variable.

Table 6 – AR model estimation for x9, *** - p-value < 0.01. Source: own calculations.

Variable	***Coefficient***	***Std. Error***	***t-ratio***
const	0.471***	0.178	2.640
l_x9_1	0.884***	0.044	19.98
R-squared	0.767		
F(3, 119)	399.1452***		
Durbin-Watson	2.026		

Results suggest that in average increase of 1% in prices in previous month will lead to 0.88% increase in prices in current month. Forecast results are shown on the Diagram 4. As can be seen in the Diagram 5, more than 80% of shock is compensated after 12-13 months and impulse response graph is fading.

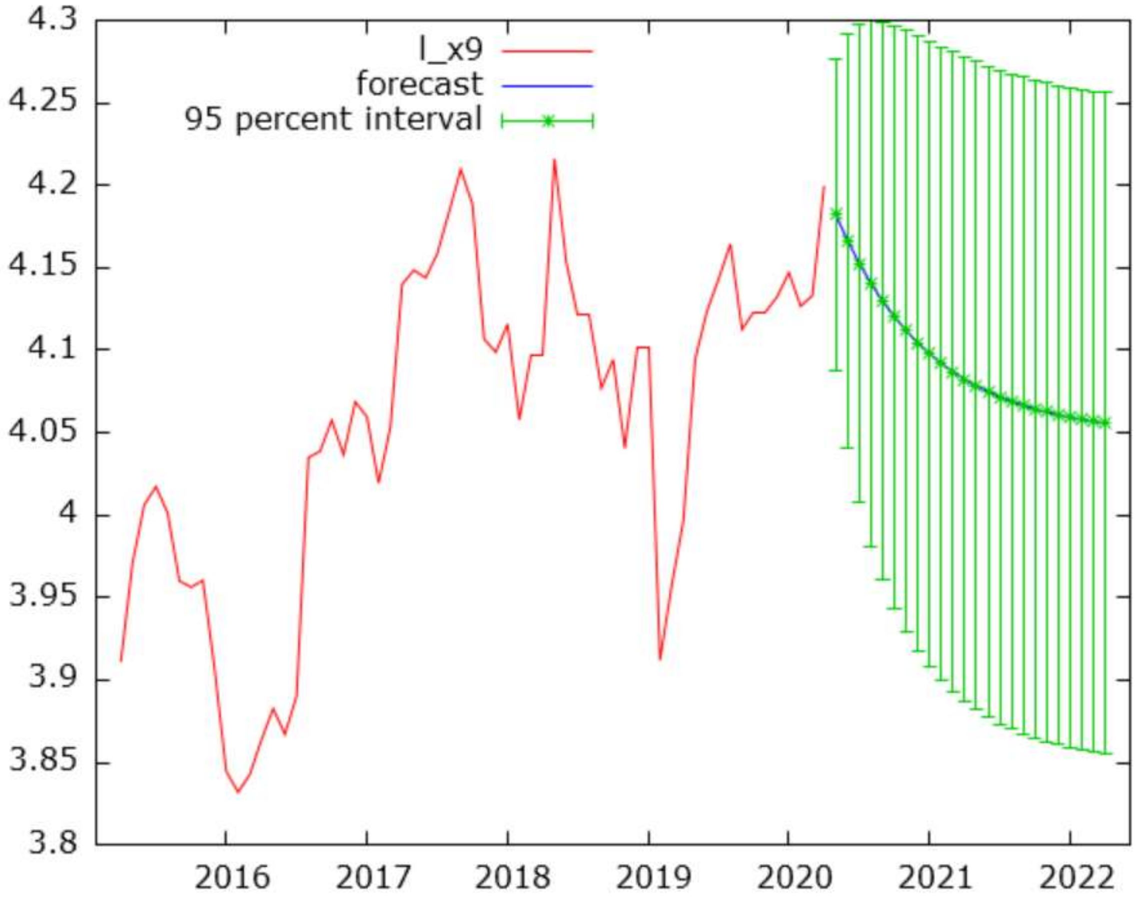

Diagram 4 – Forecast of prices of breeding piglets for 12 months with confidence interval 0.95 based on data for the period of January, 2010-April,2020. Source: own calculations

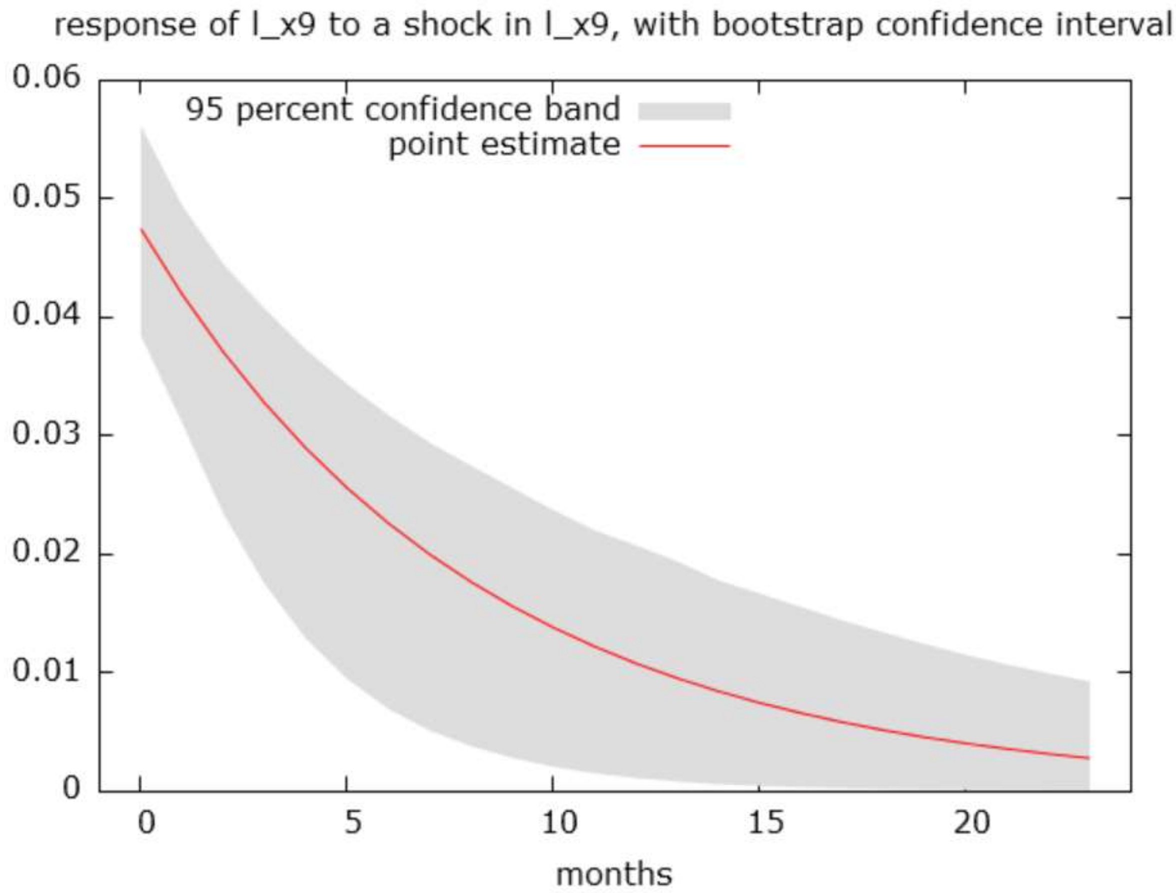

Diagram 5 – Impulse response of lnx_9 to a shock in lnx_9 with confidence interval 0.95. Source: own calculations

Prasata jatečná v živém (CZV) (Kč/kg)

For the purposes of forecasting, we use monthly prices of pigs for slaughter for the period of 2010.01 – 2020.04 and fit AR-model in the following classical form:

$$lny_{1t} = \alpha_{01} + \sum_{k=1}^{m} \alpha_k lny_{1(t-k)} + \varepsilon_t \quad (1)$$

where y_1 - endogenous variable; α_k - regression coefficients; α_{0i} – constant; ε_t – residuals; k - number of lags; m – maximum lag; i – denotes number of endogenous variable.

Table 7 – AR model estimation for y1, *** - p-value < 0.01, ** - p-value < 0.05. Source: own calculations.

Variable	***Coefficient***	***Std. Error***	***t-ratio***
const	0.204***	0.072	2.821
l_y1_1	1.750***	0.09	19.43
l_y1_2	-1.033***	0.159	-6.517
l_y1_3	0.225**	0.09	2.493
R-squared	0.955		
F(3, 119)	822.5341***		
Durbin-Watson	1.93		

Results suggest that, on average, increase of 1% in prices in previous month will lead to 1.75% increase in prices in current month. Increase of 1% in prices 2 months ago will lead to decrease of 1.03% in current month, suggesting compensating effect between prices in previous month and prices 2 months ago. At the same time, increase of 1% in prices 3 months ago will lead to increase of 0.23% in current month. Forecast results are shown on the Diagram 6. Diagram 7 shows forecast results in logarithmic scale. As can be seen in the Diagram 8, more than 80% of shock is compensated after 12-13 months and impulse response graph is fading. Diagram 9 shows impulse response function in levels of variables (in CZK).

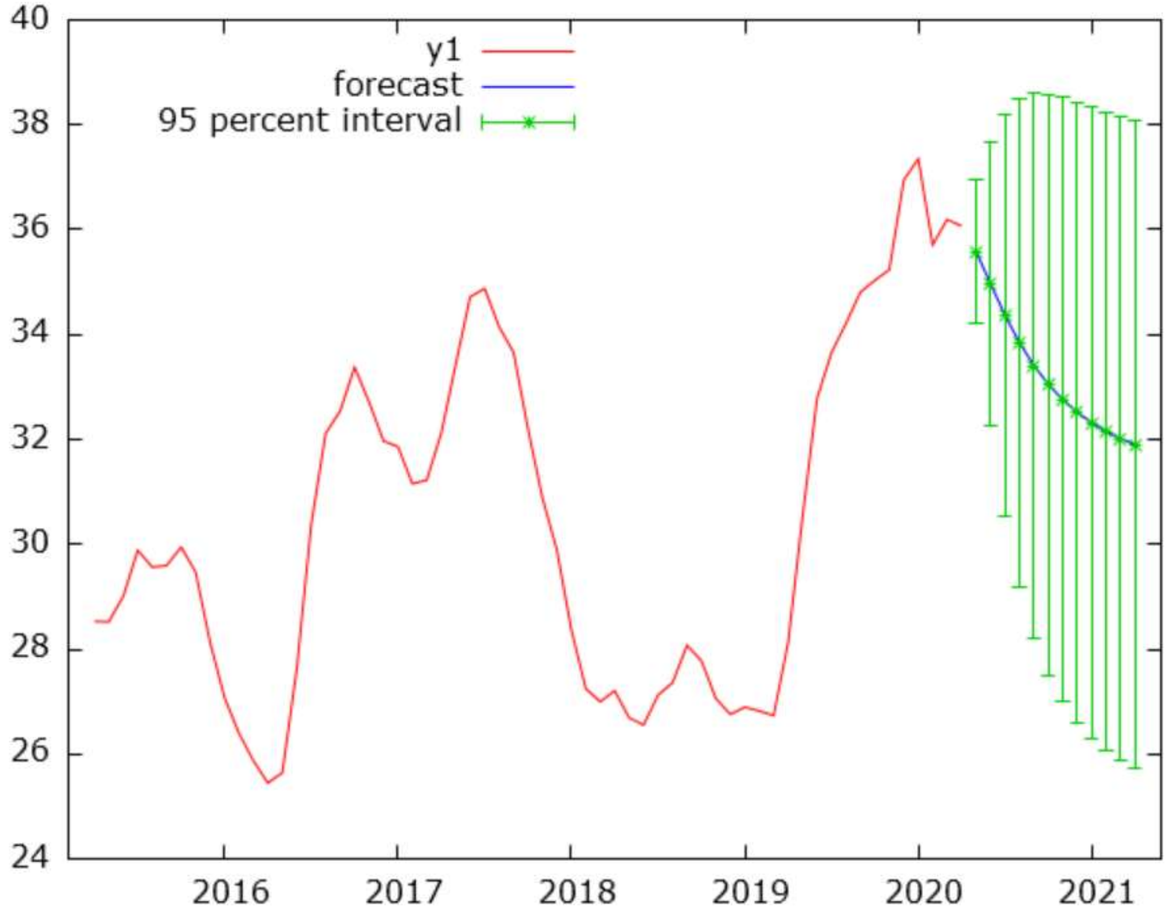

Diagram 6 – Forecast of prices of pigs for slaughter for 12 months with confidence interval 0.95 based on data for the period of January, 2010-April,2020. Source: own calculations

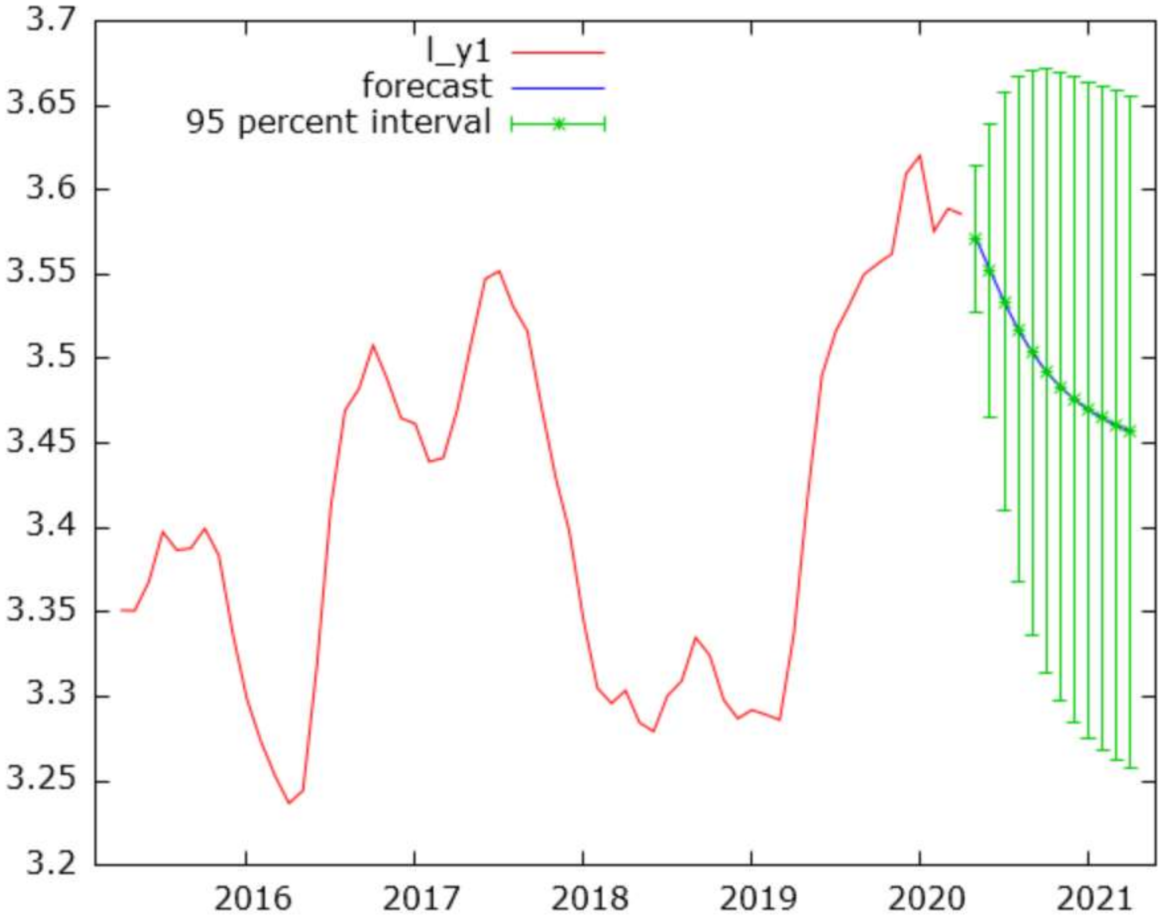

Diagram 7 – Forecast of prices of pigs for slaughter for 12 months (logarithmic scale) with confidence interval 0.95 based on data for the period of January, 2010-April,2020. Source: own calculations.

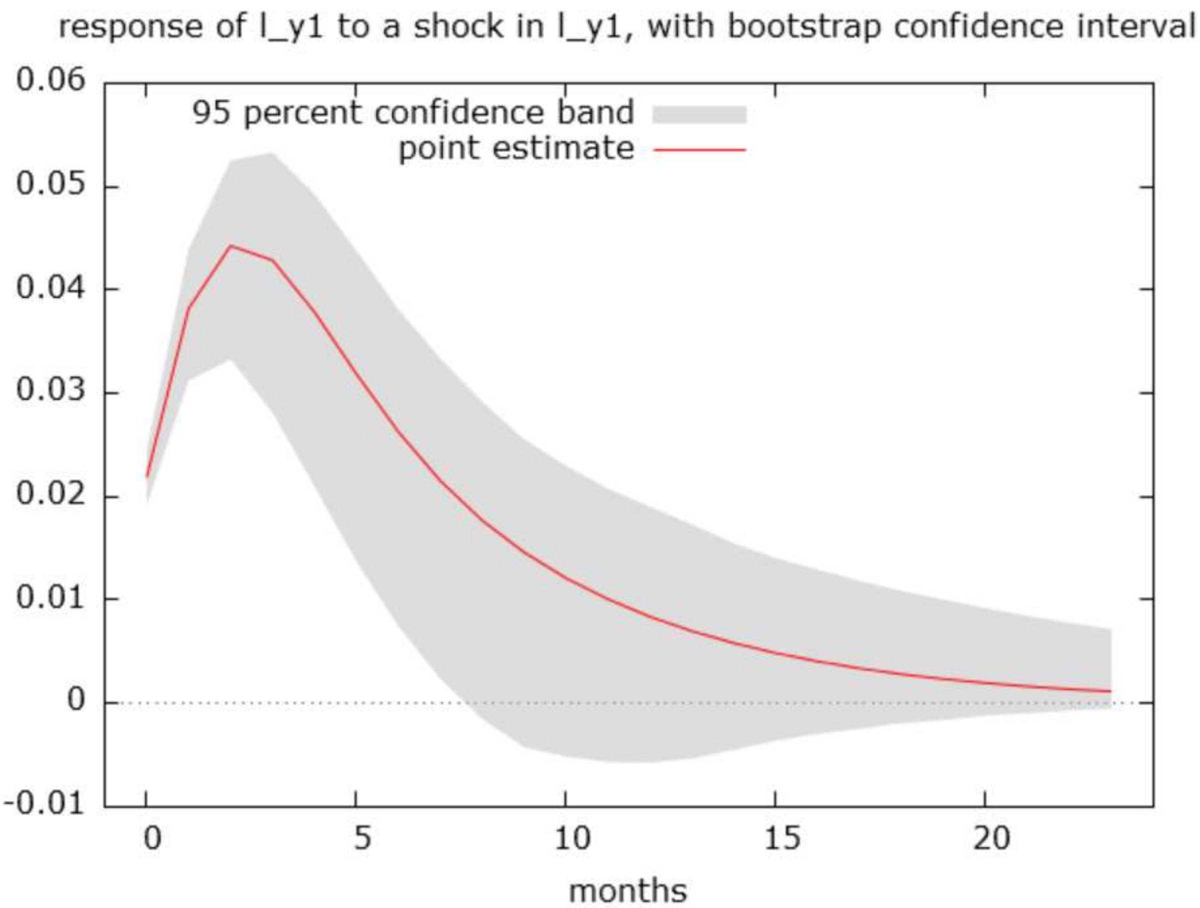

Diagram 8 – Impulse response of lny_1 to a shock in lny_1 with confidence interval 0.95. Source: own calculations.

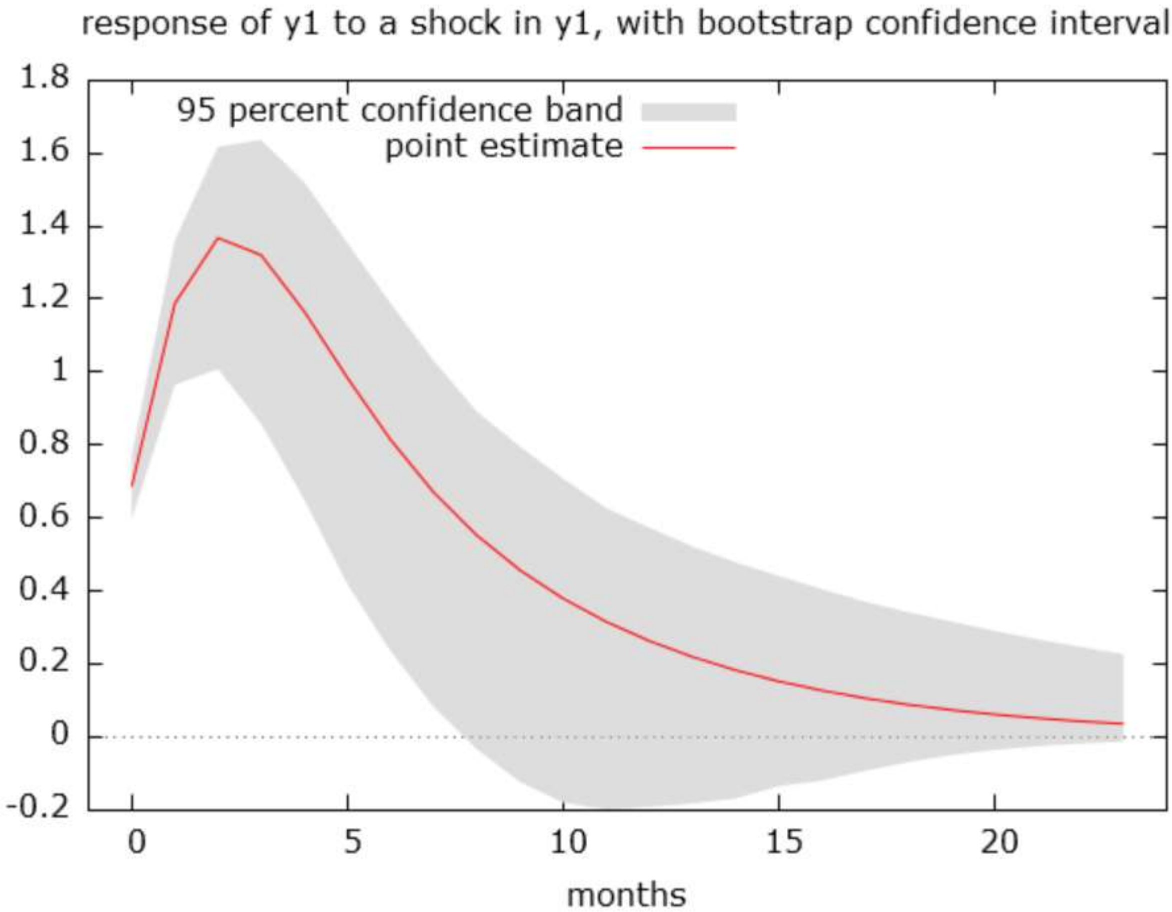

Diagram 9 – Impulse response of y_1 to a shock in y_1 with confidence interval 0.95. Source: own calculations.