doi: 10.17221/209/2016-AGRICECON

Consequences of maize cultivation intended for biogas production

Zuzana LAJDOVA, Jan LAJDA, Jaroslav KAPUSTA, Peter BIELIK

Department of Economics, Faculty of Economics and Management, Slovak University of Agriculture in Nitra, Slovak Republic

Abstract: A standard concept of biogas plants – strong maize silage concept is due to its high economic advantage as the maize silage is one of the most effective substrate for anaerobic digestion in matter of biogas yield. Increasing demand for maize silage, reflected in a rise of its price, endangers the economic effectiveness and therefore economic sustainability of the biogas sector. This situation also creates negative externalities related to upward pressure on food prices and lower livestock production. Moreover, biogas plants focused primarily on maize silage could increase the area of arable land for growing maize for energy purposes and decline the production of crops for human nutrition. The paper focuses on examination of consequences of maize cultivation intended for biogas production in case of Slovakia. The results show the impact of biogas production via anaerobic digestion on area of land used for maize production and live bovine animal production.

Key words: agriculture, biogas, land, livestock, maize

Resource strategy concerns and the need for secure, clean and efficient energy that mitigates environmental impacts associated with fossil fuels are the main drivers for deployment of renewable energy sources such as biogas. Biogas has favourable environmental aspects such as waste treatment, production of energy from waste and general substrates and a better way to spread the fermented residues via improved flow abilities (Hijazi et al. 2015). Farmers have been encouraged to produce heat and/or electricity from biogas by financial incentives in many European countries in order to not only deal with the traditional farm activities (cultivating crops and raising livestock), but also produce biogas energy that could provide a good opportunity for augmenting the farm´s earnings and generating environmental benefits for society as a whole (Torquati et al. 2014). However, increasing support for the generation of renewable energy, aimed at reduction of CO_2 emissions, in agriculture may give rise to potential conflicts with agri-environmental policies directed at land use extensification and landscape preservation (Troost et al. 2015).

European Biomass Association (2013) states that usage of biomass as bioenergy source will play the main role in achieving the ambitious goal leading to 20% of the total energy consumption to be produced by renewable sources by 2020, which is approved by the Renewable Energy Directive. Nowadays, biomass represents 2/3 of renewable energy sources in EU. Currently, RES stands for of 8.5% of final energy consumption. According to Wellinger (2014), European feed-in-tariffs support system of the electricity produced from biogas in agriculture created a successful story. Also the EU legal instruments manage the issue of treatment of bio-waste through anaerobic digestion rather than open landfilling. There are over 4000 BGPs in Germany, mostly on farms with cogeneration unit, making Germany a leader in the field. European Biomass Association (2013) adds that usage of energy crops for energy will climb in next 10–20 years and is expected that 10–20 or 30% of the arable land will gradually move from food and feed production to energy farming. Large European countries with fertile soils (e.g. France or Ukraine) may become leaders in bioenergy industry. Importance of crops like maize, sugar beet and others will rise in Europe.

However, increased demand for suitable land for biomass competes with the need for food production

Supported by the Research Centre AgroBioTech built in accordance with the project Building Research Centre "AgroBioTech" ITMS 26220220180.

doi: 10.17221/209/2016-AGRICECON

resulting in conflicts between the land use for food production and the land for producing bioenergy crops. If energy crop production is located where food crops used to be, a new land for food production is needed to be found in order to ensure stable supply of food. This fact comes along with change in crop production patterns and leads into either a displacement of food crops production or decreased production and afterwards may affect food prices and food security (Searchinger et al. 2008). Further development of biogas production via anaerobic digestion may lead into competition for land between food and energy crops and subsequently causes rise in food prices (Schön 2010). For example, the significant land use change outside of Germany is caused by German biogas production that is large enough to have sizeable effect on global agricultural markets in prices and quantities. It is also confirmed that profits in the agricultural sector increase, nevertheless, food consumers face higher prices and subsidies for biogas production are passed on the electricity consumers (Britz and Delzeit 2013). Looking at the impacts of biogas production, biogas production has also resulted in distortions in agricultural and land markets due to high guaranteed energy prices. More specifically, the implementation of biogas plants causes an intensification of land use, mainly an increase in cultivation of grass silage instead of meadows, maize instead of other crops. Additionally, the revealed intensification in the agricultural production may signify environmental risks (Ostermeyer and Schönau 2012). The increasing dependence on maize for biogas production changes the local agricultural structure, furthermore, biogas production results in crowding out of established traditional forms of production in animal husbandry and crop cultivation (Carsten et al. 2013). Thus, the additional maize entails a decrease in other crops (including rotational set-aside) and therefore a decline in habitat diversity, which might also influence the species (Gevers et al. 2011).

In Slovakia, maize silage is the most common input material into BGPs. The rest includes various wastes including biomass from livestock production. As previously mentioned, BGPs focused primarily on maize silage could increase the area of arable land for growing maize for energy purposes and decline crop production aimed at the nutrition of the population. Therefore, the paper intends to examine consequences of maize cultivation for biogas production in case of Slovakia. More specifically, the study aims to investigate whether biogas production does (a) increase maize cultivation, (b) decrease cereal production, (c) decrease livestock production in Slovakia.

MATERIALS AND METHODS

The paper intends to assess whether there is an identifiable relationship between area of maize production (Green_M) and installed electrical capacity of biogas plants (MW); area of cereals production (Cereals) and MW; number of live bovine animals (LBA) and MW in Slovakia. Installed electrical capacity is measured in megawatt per hour, area of maize production in 1 000 ha and number of live bovine animals in thousand heads. Data covering the period from 2005 until 2014 were used and obtained from Food and Agriculture Organization of the United Nations (FAOSTAT) and Regulatory Office for Network Industries (URSO).

A three stage procedure is used in order to find out the impact of biogas production on agriculture. Firstly, the most commonly used unit root test – Augmented Dickey-Fuller test (ADF) is conducted for checking the stationarity of time series. The ADF test is derived from the simple version of the Dickey-Fuller test (DF) by adding generous lagged levels of the change in the dependent variable to produce a better white-noise error term (Sebri and Abid 2012). It means that the ADF type test consists of additional higher order lagged terms and this improvement will "whiten" the error term (Geda et al. 2014). The ADF test is based on the following estimation (Yenice and Bejleri 2013):

$$\Delta y_{t=1}^{n} = \beta_1 + \alpha y_{t-1} + \gamma \sum \Delta y_{t-1} + \varepsilon_t \quad (1)$$

where y_t represents all variables (in the natural logarithmic form) at time t, Δ is the first difference operator, β_1 is a constant, n is the optimum number of lags on the dependent variable. The null hypothesis H_0, that Y_t is nonstationary, is tested against H_1, that Y_t is stationary (Shiu and Lam 2004). The most common procedure to determine lag lenght is to estimate a vector autoregression using undifferenced data and then use the same lag length tests in a traditional VAR (Ouédraogo 2010; Ciaian and Kancs 2011). The lag lenght was determined according to the Schwarz Information Criterion and Akaike Information criterion (Hao et al. 2015; Kapusuzoglu and Karacaer Ulusoy 2015).

Johansen co-integration procedure is applied after running the ADF test. Johansen test is based on the two different likelihood ratio tests, as follows:

doi: 10.17221/209/2016-AGRICECON

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \lambda_i) \quad (2)$$

$$J_{max} = -T \ln\ (1 - \lambda_{r+1}) \quad (3)$$

where T refers to the sample size and λ_i is used as the i^{th} largest canonical correlation. The hypothesis H_0: r cointegrating vectors is tested against the alternative H_1: n cointegrating vectors by the trace test and the maximum eigenvalue test examines hypothesis H_0: r cointegrating vectors against the alternative hypothesis H_1: $r + 1$ cointegrating vectors (Shirani Bidabadi and Hashemitabar 2009; Dogan 2014).

Finaly, the following form of vector error correction model (VECM) could be applied for time-series data that are nonstationary (Belloumi 2009; Busse et al. 2010; Bruns and Gross 2013; Lin et al. 2016):

$$\Delta y_t = \mu_t + \Pi y_{t-1} + \sum_{j=1}^{k} \Gamma_j \Delta y_{t-j} + \varepsilon_t \quad (4)$$

where Π refers to long run matrix and estimates the number of co-integrating vectors that consist of α and β showing speed of adjustment towards long run equilibrium and long run parameter respectively, r is the vector of parameters and refers to the short term relationship; Δ is a difference operator; y_t is a vector of non-stationary I (1) variables; μ_t represents vector of constant and ε_t is k-dimensional vector of the stochactic error term. The validity and reliability of VECM were tested by performing several diagnostic test (Breush-Godfrey test, ARCH test, Doornik-Hansen test) checking normality, autocorrelation and heteroscedasticity.

RESULTS AND DISCUSSION

Biogas sector has recorded positive continuous growth since 2009 (Act No. 309/2009 Coll. on the promotion of renewable energy sources and high-efficiency cogeneration entered into force in 2009). A guaranteed price for electricity for 15 years and priority connection to the grid were the main factors affecting the rapid development after 2009. There were already 92 biogas stations (BGPs) with total installed capacity of 91.64 MW in operation, under construction, or just before construction at the beginning of autumn 2012 in Slovakia. Out of this amount, 42 BGPs were in operation and 7 other stations were running on experimental basis. However, there was a setback in the installation of new facilities in 2014. The distribution companies have decided not to accept /or handle further requests for connecting to the grid because of the need to analyse the impact of already connected /or planned facilities on safety and operability of the distribution system since the end of 2013. In total, there were 107 biogas plants with installed electrical capacity of 101.83 MW in 2014 in Slovakia.

Nevertheless, the potential of biogas stations is still not fully exhausted. It is estimated that in case of usage of livestock manure as an input material, there is possibility for running of 280 BGPs with average installed capacity of 350 kW and an annual manure consumption of 40 000 tonnes by a BGP in Slovakia. At the same time, up to 8300 BGPs could work with average installed capacity of 500 kW with an annual biomass consumption of 600 tonnes per one biogas station in Slovakia (European Agricultural Fund for Rural Development 2012).

Maize silage is the most common input material into BGPs and the rest includes various wastes including biomass from livestock production in Slovakia. The main reason is the fact that only the price of electricity produced from the combustion of biogas produced by anaerobic fermentation technology with the overall performance up to 1 MW or more is guaranteed by the authorities. Under these circumstances investors are forced to build BGPs with bigger installed capacity and use raw material with the greatest yield of biogas for the fastest return on investment and generating profit. Therefore, BGPs focused primarily on maize silage could increase the area of arable land for growing maize for energy purposes and decrease crop production for human nutrition. About 45 tonnes of maize are needed for installed capacity of 1 MW, representing an annual need of about 16 500 tonnes of maize, respectively arable land about 410 ha (EnergiePortal 2015).

There was a substantial rise in production area of green maize from 2010 to 2013. The total area of green maize production was 93.2 thousand ha in 2013. Change in production of agricultural entities associated with growth in crop production and unstable situation in the dairy sector have also caused that the production of live bovine animals experienced the negative trend during the whole examined period in Slovakia. More specifically, 529 thousand heads of LBA were recorded in 2005, while the livestock production was at level of 465 thousand heads in 2014 (a decrease by 12.1%). Cereal production area did not recorded outright positive or negative devel-

doi: 10.17221/209/2016-AGRICECON

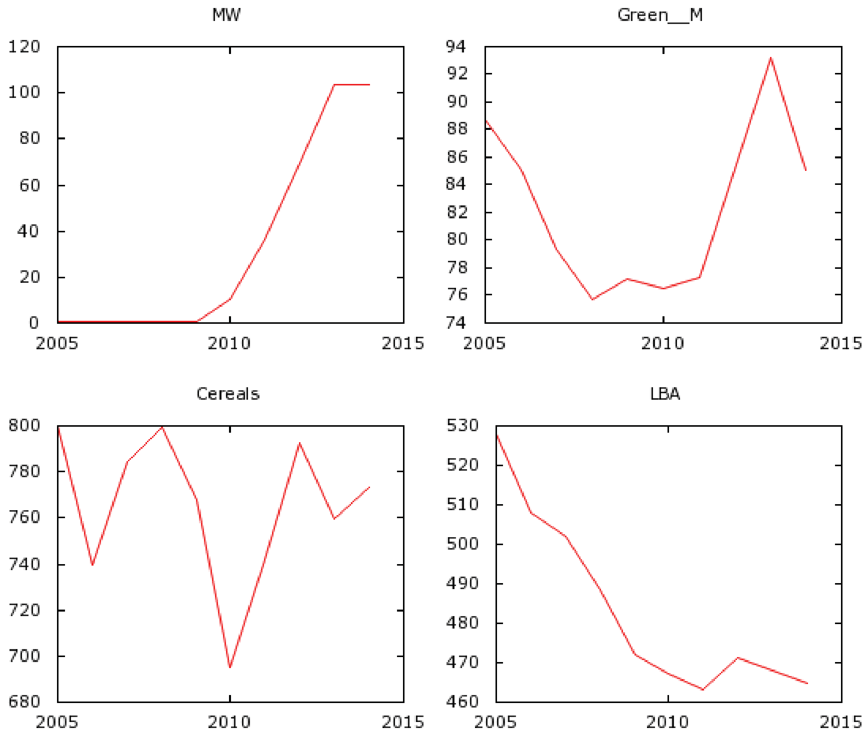

Figure 1. Development of biogas sector, land area of green maize and cereals and live bovine animal production

Source: own calculations

opment; it fluctuated over the time period and the total area of cereal production reached its minimum (694.9 thousand ha) in 2010 (Figure 1).

Correlation between installed electrical capacity and area of green maize production is strong and positive (0.58). Likewise, there is strong but negative (–0.59) correlation between installed capacity and number of live bovine animals. Value of 0.045 reveals that electric capacity and area of cereals production are weakly related in terms of the evidence of correlation (Table 1).

The ADF test fails to reject the null hypothesis of unit root suggesting that the variables are non-stationary. On the other hand ADF test of first differences rejects the null hypothesis of the unit root test; therefore, these results suggest that selected variables are integrated of order one, meaning that they are stationary in the first differences (Table 2).

The Johansen co-integration test was conducted for identifying long-term relationship among selected variables and to determine the co-integration rank.

Table 1. Correlation matrix

Variable	*p*-value
corr(MW, Green_M)= 0,57901201	0.0794*
corr(MW,Cereals) = 0,04517902	0.9014
corr(MW, LBA) = -0,59316600	0.0707*

Source: own calculations

The results suggest that both the trace test and the like hood ratio test reject the absence of co-integration relationship between MW and Green_M even at 1% significant level. The co-integration test also confirms the presence of a co-integration vector for the installed electrical capacity and the number of live bovine animals. However, the Johansen test indicates that there is no sign of co-integrating relationship between the installed capacity and the area of cereals production (Table 3).

Vector Error Correction Model indicates that estimated value of the adjustment coefficient is negative both for area of green maize production (–0.55679) with the speed of convergence to equilibrium of 56% and for installed capacity (–7.2159) in Equation

Table 2. ADF test

Variable	Augmented Dickey-Fuller test
MW	0.1491
d_MW	0.006624***
Green_M	0.5652
d_Green_M	0.005988***
Cereals	0.636
d_Cereals	0.0001***
LBA	0.5145
d_LBA	0.03151**

Source: own calculations

doi: 10.17221/209/2016-AGRICECON

Table 3. Johansen co-integration test

Models	Rank	Eigenvalue	Trace test	*p*-value	L-max test	*p*-value
MW, Green_M	0	0.97544	31.087	0.0001	29.654	0.0001
	1	0.16399	1.4329	0.2313	1.4329	0.2313
MW, Cereals	0	0.61641	9.0031	0.3719	8.6236	0.3263
	1	0.041288	0.37949	0.5379	0.37949	0.5379
MW, LBA	0	0.84933	18.733	0.0033	17.034	0.0035
	1	0.17203	1.6990	0.2257	1.6990	0.2256

Source: own calculations

l_Green_M. However, only adjustment coefficient Green_M is statistically significant. The test of weak exogeneity testing whether the adjustment parameters are significant in VECM shows that installed capacity appears to be weakly exogeneous as the null hypothesis cannot be rejected in Equation l_Green_M and the results indicate that l_Green_M is responding to a change of l_MW. In Equation l_LBA, installed electrical capacity (MW) is not statistically significant both at 5% and 1% significant level. Estimated values of adjustment coefficients have opposite signs in Equation l_LBA, meaning that there is only one equilibrium relationship between the variables. The coefficient for l_LBA carries positive sign (8.397%), meaning that the system will be unstable and divergence from the equilibrium will occur in case of any system disturbance. Additionally, the test for the weak exogeneity reveals that again only variable l_MW is weakly exogenous. To conclude, VECM shows that relationship between the pairs of considered series is not simultaneous and indicates only one-way relation with the impact of l_MW on the other series. Based on the results, an increase of electricity production from biogas increases the area used for green maize cultivation in Slovakia and decreases the livestock production in case of live bovine animals in Slovakia.

Table 4. VECM

Model	Equation: l_Green_M	Equation: l_LBA
α	l_MW −7.2159 l_Green_M −0.55679**	l_MW −3.1364* l_LBA 0.083972**
β	l_Green_M 1.0000 l_MW −0.021154 const −4.3999	l_LBA 1.0000 l_MW 0.057685 const −6.4396

Source: own calculations; the asterisk (*) denotes the significant variables at 10% level of significance; the asterisk (**) denotes the significant variables at 5% level of significance and the asterisk (***) at 1% level of significance

However, there is no sign of co-integrating relationship between area of cereals cultivation and biogas production (Table 4).

Diagnostic tests above equations were computed to examine the validity and reliability of vector error correction model. Breush-Godfrey test failed to reject the null hypothesis of no autocorrelation and the ARCH test indicated that the null hypothesis of homoscedasticity was accepted in both equations. The null hypothesis that the residuals are normally distributed was accepted as well. The regression model account for 30.54% of the variance in equation with d_l_Green_M and for 39.46% of variance is explained by the model with d_l_LBA (Table 5).

CONCLUSION

The results show that biogas industry development increases the area of land used for maize production, however, negative impact is revealed in case of live bovine animal production. On the other hand, apparently, it has no relevance for cereal production area. The findings are consistent with case of German biogas industry that more significantly affects green

Table 5. VECM diagnostic checks

Diagnostic test	Equation: d_l_Green_M	Equation: d_l_LBA
R-squared	0.305424	0.394615
Durbin-Watson statistic	1.90471	1.35929
Autocorrelation (Breusch-Godfrey test)	*p*-value 0.992	*p*-value 0.48
ARCH test	*p*-value 0.773261	*p*-value 0.71222
Normality of residuals	*p*-value 0.131636	*p*-value 0.482028

Source: own calculations

doi: 10.17221/209/2016-AGRICECON

maize cultivation, live bovine animal production as well as production of cereals (Lajdová et al. 2016). Though, VECM model does not explain all the variability of the response data that can be explained by the lower level of biogas industry development in Slovakia where only 107 BGPs were active in 2014, whereas e.g. in Germany were 7960 BGPs in operation. On the other hand, relatively strong correlation between increase in BGPs and decrease in live bovine animal production might be spurious because the decreasing trend is mainly due to low competitiveness of Slovak milk producers in comparison to the other producers from EU member states. However, even stronger biogas industry with continuing maize silage usage for anaerobic digestion (AD) could have a higher negative influence on live bovine animal production in the future. Additionally, upward trend in development of biogas sector in Slovakia without any change in maize silage usage as purposely grown input material might lead into the similar scenarios like in Germany. A standard concept of biogas plants – strong maize silage concept is due to its high economic advantage as the maize silage is one of the most effective substrate for AD in matter of biogas yield. On the other hand, increased demand for maize silage, reflected in a rise of its price, endangers the economic effectiveness and therefore economic sustainability of the biogas sector. Moreover, this situation creates negative externalities related to upward pressure on food prices, lower livestock production and cultivation of other monocultures. Therefore, an effective change in subsidy police is needed to be done in order to control input material for AD, so the input material would be biomass waste instead of purposely grown crops. However, any attempt to restrict purposely grown crop from being used in AD may decrease economic attractiveness of the biogas business, consequently the whole subsidy concept is needed to be changed in order to ensure future of biogas industry. Thus, promoting biomass waste as the input material, mostly wastes such as manure and slurry, may finally link anaerobic digestion (AD) with livestock production in larger scale. In this case, AD will not only be a mean of renewable energy production but also it will treat waste which is the main goal of the technology in the first place. Though, inequality of conditions and support mechanisms and abolition of milk quotas in EU since April 2015 have worsened the competitiveness of livestock production in Slovakia. Therefore the unstable market situation brings uncertainties in the sector and its further alliance with biogas sector is questionable.

REFERENCES

Belloumi M. (2009): Energy consumption and GDP in Tunisia: Cointegration and causality analysis. Energy Policy, 37: 2745–2753; doi: 10.1016/j.enpol.2009.03.027

Britz W., Delzeit R. (2013): The impact of German biogas production on European and global agricultural markets, land use and the environment. Energy Policy, 62: 1268–1275; doi: 10.1016/j.enpol.2013.06.123

Bruns B.S., Gross Ch. (2013): What if energy time series are not independent? Implications for Energy-GDP causality analysis. FCN Working Paper No. 10/2013. Institute for Future Energy Consumer Needs and Behaviour. Available at https://www.rwth-aachen.de/global/show_document.asp?id=aaaaaaaaaagvwal (accessed March 2016).

Busse S., Brümmer B., Ihle R. (2010): Interdependences between Fossil Fuels and Renewable Energy Market – The German Biodiesel Market. Discussion Papers No. 1010, Department für Agrarökonomie und Rurale Entwicklung, Georg-August-Universität Göttingen.

Carsten H.E., Guenther-Lübbers W., Theuvsen L. (2013): Impacts of Biogas Production on the Production Factors Land and Labour – Current Effects, Possible Consequences and Further Research Needs. International Journal on Food System Dynamics, 4: 26–38.

Ciaian P., Kancs d´Artis (2011): Food, energy and environment: Is bioenergy the missing link? Food Policy, 36: 571–580; doi: 10.2139/ssrn.1992924

Conference proceedings, Biogas Science 2014; ISBN 978-3-900932-21-3

Biogas Science 2014 (2014). Proceedings International Conference on Anaerobic Digestion, Vienna, October 26–30, 2014. University of Natural Resources and Applied Life Sciences, Vienna.

Dogan E. (2014): Energy consumption and economic growth: evidence from low-income countries in Sub-Saharan Africa. International Journal of Energy Economics and Policy, 4: 154–162.

EnergiePortal (2015): Bioplynové stanice v SR. (Biogas plants in SR.) Available at http://www.energie-portal.sk/Dokument/bioplynove-stanice-v-sr-100191.aspx (accessed May 2016).

European Agricultural Fund for Rural Development EAFRD (2012): Obnoviteľné zdroje sú príležitosťou pre farmárov pri diverzifikácii výroby. (Renewable energy sources are an opportunity for diversification of farmers' production.) Agromagazín, 12/2012.

doi: 10.17221/209/2016-AGRICECON

European Biomass Association (2013): A Biogas Road Map for Europe. Available at http://www.4biomass.eu/document/news/AEBIOM_Biogas_Roadmap.pdf (accessed April 2016).

Food and Agriculture Organization of the United Nations. FAOSTAT Statistics division. Avaliable at http://faostat3.fao.org/home/E (accessed March 2016).

Geda A., Ndung'u N., Zefru D. (2014): Applied Time Series Econometrics: a practical guide for macroeconomic researchers with a focus on Africa. The University of Nairobi Press and African Economic Research Consortium; ISBN 10-9966-792-11-2.

Gevers J., Hoye T.H., Topping C.J., Glemmnitz M. (2011): Biodiversity and the mitigation of climate change through bioenergy: impacts of increased maize cultivation on farmland wildlife. GCB Bioenergy, 3: 472–482; doi: 10.1111/j.1757-1707.2011.01104.x

Hao N., Colson G. Seong B., Park C., Wetzstein M. (2015): Drought, ethanol, and livestock. Energy Economics, 49: 301–307; doi:10.1016/j.eneco.2015.02.008.

Hijazi O., Munro S., Zerhusen B., Effenberger M. (2016): Review of life cycle assessment for biogas production in Europe. Renewable and Sustainable Energy reviews, 54: 1291-1300; doi: 10.1016/j.rser.2015.10.013

Kapusuzoglu A., Karacaer Ulusoy M. (2015): The interactions between agricultural commodity and oil prices: an empirical analysis. Agricultural Economics – Czech, 61: 410–421; doi: 10.17221/231/2014-AGRICECON

Lajdová Z., Lajda J., Bielik P. (2016): The impact of the biogas industry on agricultural sector in Germany. Agricultural Economics – Czech, 62: 1–8.

Lin B., Omoju O.E., Okonkwo J.U. (2016): Factors influencing renewable electricity consumption in China. Renewable and Sustainable Energy Reviews, 55: 687–696.

Ostermeyer A., Schönau F. (2012): Effects of biogas production on inter- and in-farm competition. Paper prepared for presentation at the 131st EAAE Seminar ´Innovation for Agricultural Competitiveness and Sustainability of Rural Areas´. Prague, Czech Republic. Available at http://ageconsearch.umn.edu/bitstream/135772/2/Ostermeyer.pdf (accessed March 2016).

Ouédraogo I.M. (2010): Electricity consumption and economic growth in Burkina Faso: A cointegration analysis. Energy Economics, 32: 524–531.

Regulatory Office for Network Industries. URSO, Bratislava. Avalaible at http://www.urso.gov.sk (accessed March 2016).

Schön M. (2010): Numerical Modelling of Anaerobic Digestion Processes in Agricultural Biogas Plants. Books on Demand, Norderstedt.

Searchinger T., Heimlich R., Houghton R.A., Dong F., Elobeid A., Fabiosa J., Tokgoz S., Hayes D., Yu T.-H. (2008): Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science, 319: 1238–1240.

Sebri M., Abid M. (2012): Energy use for economic growth: A trivariate analysis from Tunisian agriculture sector. Energy Policy, 48: 711–716.

Shirani Bidabadi F., Hashemitabar M. (2009): The induced innovation test (co-integration analysis) of Iranian agriculture. Agric. Econ. – Czech, 55: 126–133.

Shiu A., Lam P. (2004): Electricity consumption and economic growth in China. Energy Policy, 32: 47–54.

Torquati B., Venanzi S., Ciani A., Diotallevi F., Tamburi V. (2014): Environmental sustainability and economic benefits of dairy farm biogas energy production: A case study in Umbria. Sustainability, 6: 6696–6713; doi: 10.3390/su6106696

Troost Ch., Walter T., Berger T. (2015): Climate, energy and environmental policies in agriculture: Simulating likely farmer responses in Southwest Germany. Land Use Policy, 46: 50–64.

Wellinger A. (2014): Challenges and Opportunities. Universität für Bodenkultur, Wien, In: Proceedings Biogas Science 2014, Oct 26–30, 2014.

Yenice M.Y., Bejleri V. (2013): Testing for Granger Causality Between Renewable Energy Consumptio, GDP, CO_2 Emission, and Fossil Fuel Prices in the USA. Available at: https://www.asee.org/documents/sections/middle-atlantic/fall-2013/23-TESTING-FOR-GRANGER-CAUSALITY-IN-THE-USA_Yenice-Bejleri.pdf (accessed April 2016).

Received: 6th July 2016
Accepted: 23th August 2016

Corresponding author:

Zuzana Lajdová, Slovak University of Agriculture in Nitra, Faculty of Economics and Management, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic
e-mail: zuzana.lajdova@gmail.com