doi: 10.17221/292/2015-AGRICECON

The impact of the biogas industry on agricultural sector in Germany

Zuzana LAJDOVA, Jan LAJDA, Peter BIELIK

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

Abstract: The whole concept of the biogas industry is an ongoing issue particularly because of its differences from the original purpose and the criticism about causing too many externalities. Its high costs and low efficiency compared to the traditional cheaper sources belong to the main problems. This issue is serious especially currently – at the times of a slow economic growth when a switch to renewable energy sources means yet another harm to the competitiveness of the EU producers as it increases their production costs. Another weak point is that the silage maize as the most common input material for the anaerobic digestion leads to the displacement of the food crops production and it is considered to be also a contributor to the food price increase. Biogas plants also compete for input with the livestock production that ends up in the biogas plants instead of e.g. feeding cows. The aim of the paper is to investigate the long-run relationship between the biogas industry and the agricultural sector in Germany – a leader in the technology with the most developed biogas sector among the European Union member states. The econometric analysis based on the Vector Correction Model confirms the stated assumptions and concludes that the production of biogas via the anaerobic digestion has a significant impact on agriculture in Germany.

Keywords: agriculture, anaerobic digestion, biogas plnats, VECM

Agriculture is meant to be the main supplier of biomass, therefore, farmers were put to the role of electric energy producers which diversifies their business and brings them another yet stable source of income. At the same time, it helps to decentralize the electricity production and to replace the traditional fossil energy sources which are highly limited especially in Europe. Over the years, Germany has become a leader with the highest electricity production from biomass in the EU.

The most promising bioenergy option is biogas from the anaerobic digestion in Germany according to Delimit et al. (2012). Biogas production along with other renewable energy sources has been promoted by the German Renewable Energy Source Act (EEG). Thanks to the EEG, the renewable energy producers are subsidized per unit feed-in-tariffs (FITs). Blitz and Delimit (2013) point out that the aim of the Renewable Energy Act (EEG) from 2009 was to produce 30% of the total electric production generated from the RES by 2020, the EEG from 2012 increased the goal to reach the share of electric energy from the RES up to 35% by 2020 and 80% by 2050. According to the Fachverband Biogas e. V. (2012), Germany via legislation created a massive biogas sector which includes biogas operators, farmers, component producers, research and development institutions and planning agencies. The whole sector offers jobs for more than 54 thousands labour force, its share in the total export was 10% and the trade volume was 6.9 billion EUR in Germany. According to Fuchs et al. (2011), the areas that were not used before in the Schleswig-Holstein region in Germany are now used for the energy crops production and rise the income of farmers and thus the agricultural value added.

Herrmann (2012) points out that using animal manure as the main input into the biogas plant is the most beneficial way to decrease the GHG emission from the livestock production and the biogas yield may be increased by adding maize in the process. However, using maize as the main and, in many cases, the only kind of input for the anaerobic digestion creates doubts about environmental benefits of the technology, mainly aimed at waste treatment now

This work was co-funded by the European Community under the project No. 26220220180: building the Research Centre "AgroBiotech".

doi: 10.17221/292/2015-AGRICECON

used for generation of renewable energy He adds that development of bioenergy from biogas is put to a question of its environmental soundness. Similar story of bioethanol in the USA is the case of biogas in Germany where an attractive feed-in-tariff system subsidizing the technology turned Germany into the biggest biogas producer in the EU with over 7100 biogas plants in 2011 and total installed electricity capacity of 2780 MW which covers 3.1% of the total electricity demand in Germany. SRU (2007) also warns that the base input for the biogas production in Germany is maize. As the biogas industry develops, the area used for the maize production raises significantly as well. Large areas covered by the crop go hand in hand with environmental defects on soil, water and biodiversity. Furthermore, maize silage as one of the most used substrates for the AD in Germany the usage has of which became expensive over the years caused that in 2014, about 1500 German biogas plants ended up in red numbers and have already passed or will pass by bankruptcy, claim Dach et al. (2014). Wiesenthal et al. (2009) demonstrate that lately there occurred environmental and ecological concerns connected with subsidizing bioenergy industry and its fast-growing development based on the energy crops cultivation. Von Vitzke et al. (2009) support the statements above and show that in 2008 started the global food crisis which initiated discussions over the bioenergy industry land use and the competition between the food and energy crops cultivation. In 2012, the new legislation changes in Germany started to promote more large scale biogas plants and it led to more serious concerns over a higher intensity of the energy crops cultivation, especially maize, which endangers the land use and increases the food versus energy crops competition. Schwarz et al. (2012) think that over the last couple of years, the largest changes in the agricultural land use are represented by the massive increase in the maize production. The energy crop production significantly influenced land use in agriculture. A higher energy crops production initiates a growing competition for land. The energy crop production area grew from 50 000 ha in 1997 to 2.1 million ha in 2010, which is 13% of the whole agricultural land. About 70% of the total 17 million ha of agricultural land in Germany is arable land. Delzeit et al. (2010) highlight that the bioenergy policy creates circumstances for the deformation of the resource allocation so there is an abnormally stimulated move of land and capital towards the maize production. According to their research, it is obvious that the increase in maize production sacrifices the cultivation of cereals and oilseeds. Large scale maize cultivation areas create environmental issues such as the large maize monocultures, the loss of biodiversity on arable land and this strong biogas industry create upward pressures on the land rental prices due to the increasing prices of energy crops. Herrmann (2012) also finds out that the high density of biogas plants is connected with the large scale maize cultivation which comes hand in hand with several issues, especially in the case of the lack of crop rotations, such as the high amount of digestate endangering surface and ground water with pollution, climate-relevant gases emissions and soil degradation. Klawitter (2012) points out another issues connected with biogas. Entire regions in Germany are now covered by maize as a result of the subsidies for the biogas industry. The attempt to turn Germany into a bio-wonderland by building a high number of small biogas plants has led into the revolution in the field where maize is being grown on 810 thousands hectares. The idea was created eight years ago when farmers were subsidized by set-aside premiums due to the overproduction and price decreasing tendencies of agricultural commodities. The outcome is that in 2012 the country was not self-sufficient in the grain production for the first time over the past 25 years. Dairy farmers in Germany lost number of fields to biogas companies growing maize which will end up in the biogas plants instead of feeding cows. Now farmers have to buy feed from abroad which price is constantly increasing. Another externality, he adds, is that the corn producers grow corn on the same fields year after year which causes the soil degradation, a decreasing amount of animal species in the area and higher usages of pesticides. This is usually overcome via the crop rotation as a standard farming practice which, however, cannot be used due to the constant need of maize for biogas plants. According to Emman et al. (2013), the production based mainly on the maize changes pattern of the local agriculture production causing that Germany is self-sufficiency in production of fodder and other nutrients which have to be imported. Furthermore, the large biogas production in Germany caused an increase in the land rent and its price as a production factor, the production costs of food go up and it decreases the competitiveness of farmers in the region. They state that there is also a threat of the crowding out effect on the traditional production which can influence the whole regional food supply chains and even the whole vertical chain.

doi: 10.17221/292/2015-AGRICECON

Bruns et al. (2009) argue that there was a question whether to keep on subsidizing small and medium plants that would receive incentives or to promote more efficient larger plants which would profit more. It was immediately obvious that the large-scale plants might have increased the negative externalities for the regions from the environmental point of view.

The aim of this paper is to investigate the impacts of the biogas production via the anaerobic digestion on the agricultural sector in Germany – the leader of the AD in Europe. In order to fulfil the goal, the following hypotheses are formulated and reviewed: (1) It can by assumed that an increase of the electricity production from biogas increases the area used for the green maize cultivation in Germany; (2) It can by assumed that an increase of the electricity production from biogas decreases the area used for the cereals cultivation in Germany; (3) It can by assumed that an increase of the electricity production from biogas decreases the livestock production in the case of the live bovine animals in Germany.

MATERIALS AND METHODS

The annual data from 1999 to 2014 are used in order to analyse the impact of the biogas industry on agriculture in Germany. The paper investigates the relationship between area of the maize production (Green_M) and the installed electrical capacity of biogas plants (MW); the area of cereals production (Cereals) and MW; the number of live bovine animals (LBA) and MW. The installed electrical capacity is measured in megawatt per hour, the area of maize production in 1000 ha and the number of live bovine animals in thousand heads. The data are taken from the Fachverband Biogas e.V. /German Biogas Association and the Food and Agriculture Organization of the United Nations (FAOSTAT). The following time series econometric procedure is used in order to fulfil the goals and the stated hypotheses.

Firstly, the correlation analysis is performed in order to find if there is any correlation between the variables. The null hypothesis is that the two variables are linearly independent or uncorrelated. Fenton and Neil (2012) explain that the closer is the correlation coefficient to 1, the higher is the probability that there is a positive linear correlation, and the closer to –1, the higher is the probability that there is a negative linear correlation. Secondly, the stationarity of the time series is tested by the Augmented Dickey- Fuller (ADF) test in order to examine whether the series are integrated in the same order. The null hypothesis of a unit root is rejected if a variable is stationary. Bekhet (2009) states the following equation for the ADF test:

$$\Delta Y_t = \beta_1 + \beta_2 t + \alpha Y_{t-1} + \delta_3 \sum \Delta Y_{t-1} + \varepsilon_t \qquad (1)$$

where ε_t refers to an error term, β_1 is the time trend and Δ is the differencing operator. It means that $\Delta Y_t - \Delta Y_{t-1}$ is stationary, if Y_t follows the equation and ΔY_t follows a random walk. Coefficients of one period lagged value Y_{t-1} and ΔY_{t-1} are identified by α and δ. In the ADF test, it tests whether $\alpha = 0$, therefore, the null and alternative hypothesis of the unit root tests can be formulated as follows:

H_o: $\alpha = 0$ (Y_t is non-stationary or there is a unit root).

H_1: $\alpha < 0$ (Y_t is stationary or there is no unit root).

Additionally, the Johansen co-integration test is used for exploring the presence of a long run relationship between the variables and to determine the number of co-integration equations (Kapusuzoglu and Ulusoy 2015). Mukhtar and Rasheed (2010) say that the Johansen co-integration test is based on two likelihood ratio tests: the Trace test (λ_{trace}) and the maximum eigenvalue test (λ_{tmax}). Aga (2014) explains that the null hypothesis states that no variable is co-integrated. The research is focused on the two Johansen tests: the trace test for the hypothesis and the λ-max test for hypothesis on the individual eigenvalues in order to determine the number r, co-integrating vector. The tests are based on the following equations:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{g} (1 - \lambda_i) \qquad (2)$$

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

where λ_i is the value estimation for the i^{th} ordered eigenvalue from the matrix of Π, r denotes the number of co-integrating vectors under the hypothesis. λ_{trace} test (r) is conducted to test the hypothesis H_0: rank $\Pi \leq r$ against the alternative H_1: rank $\Pi > r$. λ_{max} $(r + 1)$ is used to test the hypothesis H_0: rank $\Pi \leq r$ against alternative H_1: rank $\Pi = r + 1$ (Kočenda and Černý 2014). Furthermore The VECM model is computed in order to find out whether the development of the renewable electricity production from biogas in Germany affects the area of maize production in Germany in the long run. Moreover, this approach allows distinguishing between the short run and long run causality. The vector error correction model can lead to a better understanding of the nature of

doi: 10.17221/292/2015-AGRICECON

any non-stationarity among different component series and used to identify the equilibrium or a long-run relationship among the variables. Mukhtar and Rasheed (2010) explain that the coefficient of the lagged error-correction term is a short term adjustment coefficient and shows the proportion by which the long run disequilibrium in the dependent variable is being corrected in each short run. Due to the fact that the error correction coefficient reflects the speed of adjustment to the new equilibrium, the following rule is applied: the larger the EC coefficient as an absolute value, the faster the variable will reach a new equilibrium (Schmitz and Moleva 2013). Moreover, the weak exogeneity approach is carried out in order to detect the long-run causality. According to Schreiber (2012), the weak exogeneity means that a variable is not (Granger-) caused by others in the long run. A variable that is weakly exogenous may affect other variables, but it does not adjust to the disequilibrium in the co-integrating relations (Kapounek and Králová, 2014). Sjo (2008) defines the form for the VECM as follows:

$$\Delta x_t = \sum_{i=1}^{k-1} \Gamma_i \Delta x_{t-1} + \Pi_{x_{t-1}} + \mu_0 + \Psi D_t + \varepsilon_t \qquad (4)$$

where Π is the matrix of variables. The rank of the Π matrix determines the number independent rows in Π, and also the number of co-integrating vectors. If the Π has a reduced rank, there are co-integrating relations among the x: s. Thus, the rank (Π) = 0, implies that all x's are non-stationary. If the rank (Π) = p, (full rank) then all variables in x_t must be stationary. If Π has reduced rank, $0 < r < p$, the co-integrating vectors are given as $\Pi = \alpha\beta'$ where β_i represents the i^{th} co-integration vector and α_j represents the effect of each co-integration vector on the $\Delta x_{p,t}$ variables in the model. Finally, several diagnostic tests, such as that of normality, autocorrelation and heteroscedasticity, were conducted in order to examine the validity and reliability of the vector error correction model.

RESULTS AND DISCUSSION

During the observed period 1999–2014, the biogas sector and the area used for the green maize cultivation recorded a dramatic growth, while the production of live bovine animals decreased significantly. The land area for the cereals production has the most unbalanced trend among all four variables with a decreasing development. The minimal electrical capacity was 50 MWh in 1999, since then it grew over the whole period and reached the value of 3804 MWh in 2014. In 1999, the area for the green maize cultivation was 1203 thousand hectares and in 2014 it was almost doubled, 2093 thousands hectares. Live bovine animals recorded 14 658 thousand pieces, while over the years it dropped to 12 742.19 pieces in 2014. The cereals production observed several ups and downs starting at 6635 thousand hectares, with the maximum of 7045 thousand hectares in 2001 and 6469 thousand hectares in 2014, when it reached its minimum during the observed period (Figure 1).

An overview of the German Feed-in-Tariffs in the case of the biomass utilization from year 2012 to 2014 are shown in Table 1.

Results from the correlation analysis between the area of the green maize production and the installed electrical capacity of biogas plants in Germany revealed a high and positive correlation (98.82%). The null hypothesis that the two variables are linearly independent or uncorrelated is rejected for all performed cases (Table 2). There is a high negative correlation (–74.52%) between the installed el. capacity and the

Table 1. German Feed-in-Tariffs for years 2012–2014

Electric capacity	Subsidies ct/kWh			
	2012	2013	2014 (01–07)	2014 (08–)
Basic tariff				
Up to 150 kW	14.3	14.01	13.73	13.66
Up to 500 kW	12.3	12.05	11.81	11.78
Up to 5 MW	11	10.78	10.56	10.55
Up to 20 MW	6	5.88	5.76	5.85
Tariff biowaste installations and small manure gas				
Biowaste ferm. up to 500 kWel	16	15.68	15.37	15.26
Biowaste ferm. from 500 kWel up to 2 Mwel	14	13.72	13.45	13.38
Manure biogas up to 75 kWel	25	24.5	24.01	23.73

Source: Lang and Lang (2014)

Table 2. Correlation matrix

Variable	p-value
corr(MW, Green_M) = 0.98817198	0.0000
corr(MW,Cereals) = –0.74524373	0.0009
corr(MW, LBA) = –0.72229417	0.0016

Source: own calculations

doi: 10.17221/292/2015-AGRICECON

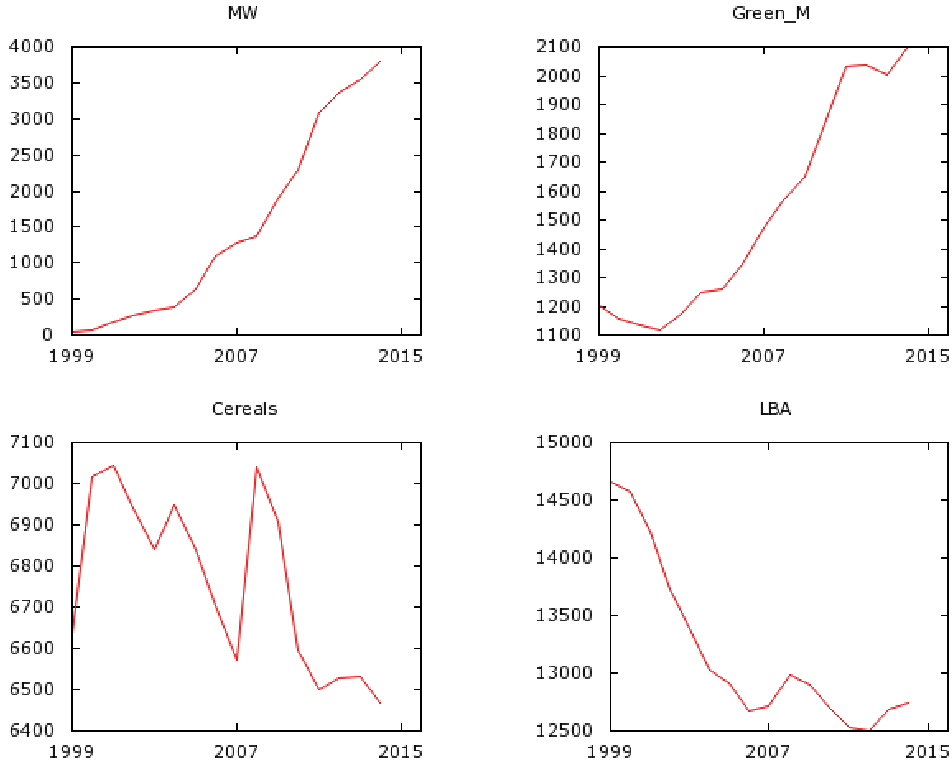

Figure 1. Development of the biogas sector, the green maize and cereals production area and the live bovine animals' production

Source: own calculations

area of cereals cultivation, and between the installed el. capacity and the number of live bovine animals (–72.23%). The rejection of the null hypothesis is confirmed by the p-value lover than 0.05 in all cases indicating that the results of the analysis are statistically significant and there are relationships between the analysed pairs of variables.

The hypothesis "The time series have a unit root and are not stationary" was accepted for all selected variables (Table 3). The ADF test confirmed all series to be non-stationary and integrated of the first order I (1) both at 1 and 5 percent significance level. The ADF test of first differences accepted the alternative hypothesis of the unit root test, meaning that the variables are stationary in the first differences.

Table 3. ADF test

Variable	Augmented Dickey-Fuller test
	p-value
MW	0.6645
d_MW	0.05604
Green_M	0.2282
d_Green_M	0.0448
Cereals	0.2661
d_Cereals	0.003032
LBA	0.5723
d_LBA	0.0004596

Source: own calculations

Once the series are found to be integrated of the same order, we could proceed to the next step and performed the co-integration analysis. The Johansen test proved the relationship between the pairs of the considered series in the long-run (Table 4).

The co-integration analysis does not provide any information concerning the direction of causality,

Table 4. Johansen co-integration test

Models	Rank	Eigen value	Trace test	*L*max test
MW, Green_M	0	0.75403	24.449	21.038
	1	0.20340	3.4110***	3.4110***
MW, Cereals	0	0.70346	18.452	18.233
	1	0.014448	0.21830***	0.21830***
MW, LBA	0	0.78777	20.169	20.151
	1	0.0013848	0.018015***	0.018015***

Source: own calculations; *, **, ***statistically significant at the 10%, 5% and 1% significance level

doi: 10.17221/292/2015-AGRICECON

Table 5. VECM

Model	Equation: l_Green_M	Equation: l_Cereals	Equation: l_LBA
α	l_MW 0.65668 l_Green_M-0.27765**	l_MW –1.4731 l_Cereals –0.58891***	l_MW 1.1782 l_LBA –0.48032**
β (co-integrating vectors)	l_Green_M 1.0000 l_MW –0.32004 const –5.1324	l_Cereals 1.0000 l_MW 0.030194	l_LBA 1.0000 l_MW 0.016795

Source: own calculations; *, **, ***statistically significant at the 10%, 5% and 1% significance level

therefore, the causality in non-stationary time series is investigated through the Vector Error Correction Model (VECM). The model is efficient even for the small time lengths; α represents the coefficient of adjustment to the equilibrium or the error correction term (ECT). The estimated coefficient of the error correction term of l_Green_M is statistically significant. The results also indicate that the coefficient of the error correction term of the cereals production variable is statistically significant at 1%. Both coefficients carry the negative sign indicating the stability of the system and the convergence towards equilibrium if any disturbance appears in the system. The speed of convergence to equilibrium is 27.77% in case of l_Green_M. The error correction coefficient of about –0.59 and it suggests that about 59% of the discrepancy between the long-term and short-term l_Cereals is corrected within one year. The EC term of l_LBA is statistically significant at 5% and carries the negative sign. It implies that the restoration to the equilibrium path will not take a long time due to the fact that the ECT value (0.48032) is high enough. The coefficient for l_MW carries a positive sign in the case of model with l_Green_M and model with l_LBA, however, no adjustment will be made in the long run, since the error correction term of l_MW is insignificant even at the 10 percent significance level. It indicates that l_Green_M, l_Cereals and l_LBA are responding to a change of l_MW. It should also be noted that the error correction coefficients have opposite signs in the equations l_Green_M and l_LBA, because there is only one equilibrium relation between the variables. The weak erogeneity hypothesis could not be rejected and it was valid for l_MW in all examined cases. The only variable that is weakly exogenous to the long-run relationship is l_MW. The VECM revealed that relationship between the pairs of the considered series is not simultaneous and indicated only one-way relation with the impact of l_MW on the other series (Table 5).

Table 6. VECM diagnostic checks

Diagnostic test	Equation: l_Green_M	Equation: l_Cereals	Equation: l_LBA
R-squared	0.789088	0.509482	0.777255
Durbin-Watson statistic	1.62653	1.82847	2.18656
Autocorrelation (Breusch-Godfrey test)	*p*-value 0.491	*p*-value 0.781	*p*-value 0.562
ARCH test	*p*-value 0.690752	*p*-value 0.992324	*p*-value 0.113193
Normality of residuals	*p*-value 0.798161	*p*-value 0.000437079	*p*-value 0.639541

Source: own calculations

We considered the VECM with the optimal number of lags checked by the Durbin-Watson statistic. The Breusch-Godfrey test was computed in order to test autocorrelation and the null hypothesis of no autocorrelation was not rejected and the ARCH test indicated that the null hypothesis of homoskedasticity was accepted in all cases. Additionally, the test of normality on the residuals was performed to check whether the residuals were normally distributed. The null hypothesis is that the residuals are normally distributed, thus the null hypothesis cannot be rejected according to the p-value and the residuals are normally distributed. However, the test of normality on the residuals showed that the residuals are not normally distributed in the equation with l_Cereals. The regression model accounts for 78, 9% of the variance in equation with l_Green_M and for 77, 7% of variance in equation with l_LBA. Approximately 50% of the variance is explained by the model with l_Cereals (Table 6).

CONCLUSION

The biogas industry significantly affects the green maize cultivation and the live bovine animal production in Germany and tends to have an impact on the production of cereals. The stated hypotheses were confirmed and we conclude that an increase of elec-

doi: 10.17221/292/2015-AGRICECON

tricity production from biogas raises the land area used for the green maize cultivation in Germany. Additionally, a decrease in area used for the cereal cultivation as well as a drop down in the livestock production in the case of live bovine animals in Germany were caused by an increase in the electricity generation from biogas. These finding can be explained by the huge German biogas industry demand for the silage maize which increases the area of the production for green maize to meet the whole demand. As the production area tends to be inelastic, the increased area for the green maize cultivation seems to sacrifice the area for other commodities cultivation. Cereals are not an exception. As the demand for food crops does not decrease and at the same time the decrease in its supply creates an upward pressure on food prices, it means that a rise in the number of the BGPs increases the level of the food price. Moreover, a negative correlation between the biogas sector development and the live bovine animal production is the evidence that meeting the demand for the BGPs means a less supply for the animal production, hence it creates an additional upward pressure on the food prices, especially when the demand for meat is globally increasing due to a higher demand in the Asian countries. The results are in line with the findings by other researchers, e.g. Klawitter (2012) who reports that the constant need of maize for the biogas production results in growing corn on the same fields year after year which causes the soil degradation, a decreasing amount of animal species in the area and a higher usage of pesticides which is usually overcome via the crop rotation as a standard farming practice which, however, cannot be used due to the constant need of maize for the biogas plants. Seachinger et al. (2008) also claim that the energy crop production comes along with the change in the crop production patterns and leads into either a displacement of the food crop production or a decrease of its production and afterwards an increase in the food prices. Nevertheless, the biogas energy is essential for the energy security and a sustainable energy system in the whole EU, therefore, in order to eliminate negative externalities, a greater emphasis must be placed on the change of the continual strong subsidy policy of the biogas sector in Germany as well as the support mechanism should be reconsidered in other EU countries that without a distinguishing input, the substrate biogas sector will lead to a significant increase in land area used for the green maize cultivation and consequently a sharp increase in the food prices and a decrease in the livestock production in the EU.

REFERENCES

Aga A.K. (2014): The impact of foreign direct investment on economic growth: a case study of Turkey 1980–2012. International Journal of Economics and Finance, 6: 71–84.

Bekhet A.H. (2009): Assessing the relationship between oil prices, energy consumption and macroeconomic performance in Malaysia: Co-integration and Vector Error Correction Model (VECM) approach. International Business Research, 2: 152–175.

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.

Bruns E., Ohlhorst D., Wenzel B., Koppel J. (2009): Renewable Energies in Germany`s Electricity Market. A Biography of the Innovation Process. Berlin: Universitätsverlag der TU Berlin.

Dach J. et al. (2014): The economic efficiency of maize straw usage as a co-substrate for biogas production. In: Biogas Science 2014, International Conference on Anaerobic Digestion, Oct 26–30, 2014, Vienna, Austria.

Delzeit R., Britz W., Kreins P. (2012): An Economic Assessment of Biogas Production and Land Use under the German Renewable Energy Source Act. Kiel Working Paper No. 1767, Kiel Institute for the World Economy, Germany. Available at https://www.ifw-members.ifw-kiel.de/publications/an-economic-assessment-of-biogas-production-and-land-use-under-the-german-renewable-energy-source-act-2/KWP_Delzeit_Britz.pdf (accessed September 2015).

Delzeit R., Gömann H., Holm-Müller K., Kreins P., Bettina Kretschmer, Münch J., Peterson S. (2010): Analysing Bioenergy and Land Use Competition in a Coupled Modelling System: The Role of Bioenergy in Renewable Energy Policy in Germany. Kiel Working Paper No. 1653, Kiel Institute for the World Economy, Germany. Available at https://www.ifw-members.ifw-kiel.de/publications/analysing-bioenergy-and-land-use-competition-in-a-coupled-modelling-system-the-role-of-bioenergy-in-renewable-energy-policy-in-germany/kwp-1653.pdf (accessed September 2015).

Emmann C.H., Guenther-Lubbers 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: 38–50.

doi: 10.17221/292/2015-AGRICECON

Fachverband Biogas e.V. (German Biogas Association and Food.) Available at http://www.biogas.org (accessed August 2015).

Fenton N., Neil M. (2012): Risk Assessment and Decision Analysis with Bayesian Networks. CRC Press, Boca Raton.

Food and Agriculture Organization of the United Nations (FAOSTAT). Available at http://faostat3.fao.org/home/E (accessed August 2015).

Fuchs C., Bogatov V., Eimannsberger J. (2011): Competitiveness and risk of crop production, milk production and biogas production with respect to regional resources. Journal of Agricultural Science & Technology, 1: 939–949.

Herrmann A. (2012): Biogas production from maize: current state, challanged and prospects. 2. Agronomic and environmental aspects. BioEnergy Research, 6: 372–387.

Kapounek S., Kralova J. (2014): Financial Instability and Money Velocity: Evidence from the Financial Crisis. MENDELU Working Papers in Business and Economics 44/2014. Mendel University in Brno. Available at http://ftp.mendelu.cz/RePEc/men/wpaper/44_2014.pdf (accessed September 2015).

Kapusuzoglu A., Ulusoy M.K. (2015): The interactions between agricultural commodity and oil prices: an empirical analysis. Agricultural Economics – Czech, 61: 410–421.

Klawitter N. (2012): Corn-mania: Biogas Boom in Germany Leads to Modern-Day Land Grab. Spiegel Online International. Available at http://www.spiegel.de/international/germany/biogas-subsidies-in-germany-lead-to-modern-day-land-grab-a-852575.html (accessed September 2015).

Kočenda E., Černý A. (2014): Elements of Time Series Econometrics: An Applied Approach. Karolinum Press. Charles University in Prague.

Lang M., Lang A. (2014): German Feed-in-Tariffs 2014 (from 08). German Energy Blog. Available at http://www.germanenergyblog.de/?page_id=16379 (accessed September 2015).

Mukhtar T., Rasheed S. (2010): Testing long-run relationship between exports and imports: Evidence from Pakistan. Journal of Economic Cooperation and Development, 31: 41–58.

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.

Schmitz M., Moleva P. (2013): Determinants for Level and Volatility of Agricultural Commodity Prices on International Markets – are Biofuels Responsible for Price Volatility and Food Insecurity? Institute for Agricultural Policy and Market Research and Center for International Development and Environmental Research, Justus Leibig University Giessen. Available at http://www.biokraftstoffverband.de/tl_files/download/Stellungnahmen_und_Studien/14-04-09-Studie%20Schmitz%20engl%20-%20VDB%20Ufop.pdf (accessed September 2015).

Schreiber S., (2012): Estimating the natural rate of unemployment in euro-area countries with co-integrated systems. Applied Economics, 44: 1315–1335; DOI 10.1080/00036846.2010.53954

Schwarz G., Noe E., Saggau V. (2012): Comparison of bioenergy policies in Germany and Denmark. Research in Rural Sociology and Development, 18: 235–262.

Sjo B. (2008): Testing for Unit Roots and Cointegration. Linköping University, Sweden. Available at https://www.iei.liu.se/nek/ekonometrisk-teori-7-5-hp-730a07/labbar/1.233753/dfdistab7b.pdf (accessed September 2015).

SRU (German Advisory Council on the Environment) (2007): Climate Change Mitigation by Biomass, Special Report. Available at http://eeac.hscglab.nl/files/D-SRU_ClimateChangeBiomass_Jul07.pdf (accessed September 2015).

von Vitzke H., Noleppa S., Schwarz G. (2009): World food security and global warming. Farm Policy Journal, 6: 59–69.

Wiesenthal T., Leduc G., Christidis P., Schade B., Pelkmans L., Govaerts L., Georgopoulos P. (2009): Biofuel support policies in Europe: Lessons learnt for the long way ahead. Renewable and Sustainable Energy Reviews, 13: 789–800.

Received: 14th August 2015
Accepted: 6th October 2015

Contact address:

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