ASPECTS OF PRIMARY PRODUCTION EVOLUTION OF NATURAL GAS IN EU-28 AND IN SOME NON-EU COUNTRIES

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Abstract— The aim of this paper is that of identifying the characteristics of the evolution of the primary production of natural gas in the EU-28 as well as in other non-EU countries from 2003 to 2014.

Keywords— ANOVA methodology, primary production of natural gas, regression line, weight of the clusters' production

I. INTRODUCTION

According to [1] world natural gas production increased by 1.6% in 2014, four times the growth rate of global consumption (+0.4%).

Related to the production as is stated in [2] natural gas can be found in a variety of different underground formations including: shale formations, sandstone beds and coal seams. Also, is mentioned that like oil production, some natural gas flows freely to wells because the natural pressure of the underground reservoir forces the gas through the reservoir rocks.

II. METHODOLOGY

For the analysis of the features of the evolution of natural gas primary production in the EU-28, out of the 28 states, the ones on which available data did not exist in the initial data series [3] or elsewhere and the ones whose production is virtually non-existent (Belgium, Cyprus, Estonia, Lithuania, Latvia, Luxembourg, Malta, Portugal, Finland and Sweden) have been eliminated. This process resulted in 18 data series which characterise the evolution of production in the EU-28. Moreover, five data series which corresponded to the primary production of natural gas in all the five states from the non-EU group were used. The 95% Confidence level, which corresponds to the significance threshold α =0.05, was chosen in order to test the statistical hypotheses regarding mean values and their confidence intervals.

Consider the data series $X = \{x_i\}_{i=\overline{1,n}}$. For its explanation we computed the mean (\overline{x}) , the limits of the confidence interval:

$$\bar{\mathbf{x}} = \pm \mathbf{S} \, \mathbf{td} \cdot \mathbf{Er} \cdot \mathbf{t}_{\frac{\alpha}{2}, \mathbf{n}-1} \tag{1}$$

$$\mathbf{Std.Er} = \frac{1}{\sqrt{n}} \cdot \sqrt{\sum_{i=1}^{n} \left(\mathbf{x}_{i} - \overline{\mathbf{x}}\right) / (n-1)}$$
(2)

as well the coefficient of variation

$$\mathbf{v} = \mathbf{s}/\mathbf{x} \tag{3}$$

Furthermore, for the comparability of several data series, we used normal (Z) series obtained by means of the following transformation:

$$\mathbf{z}_{i} = \frac{\mathbf{x}_{i} - \mathbf{x}}{\mathbf{s}} \tag{4}$$

In order to test the statistical significance of the variables' mean values, the tested hypotheses are:

- $H_{0_{-1}}$: the mean of the analysed variable is not statistically significant (the confidence interval for the variable mean includes the 0 value; the limits of the confidence interval are of different signs).
- H_{1_1} : the mean of the analysed variable is statistically significant (the confidence interval for the variable mean does not include the 0 value; the limits of the confidence interval have the same sign).

Linear models were used to determine the characteristics of the evolution of natural gas primary productions through time, to establish the annual average score and to test their statistical significance as follows:

$$\mathbf{y} = \hat{\mathbf{y}} + \boldsymbol{\varepsilon}, \quad \hat{\mathbf{y}} = \hat{\mathbf{a}} + \hat{\mathbf{b}} \cdot \mathbf{x}$$
 (5)

The validation of the regression model (5) was carried out by means of the ANOVA methodology. The statistics of the test are:

$$\mathbf{F}_{c} = \frac{\sum_{i=1}^{n} \left(\hat{\mathbf{y}}_{i} - \overline{\mathbf{y}} \right)}{k} / \frac{\sum_{i=1}^{n} \left(\mathbf{y}_{i} - \hat{\mathbf{y}}_{i} \right)}{n - k - 1}$$
(6)

Considering that α =0.05 then, according to the values of F_{0.05,k,n-k-1} the hypotheses of the test are

 $H_{0,2}$: the linear model is not statistically significant (Fc<F_{0.05,n1,n2} which is equivalent to Sig.F>0.05).

 H_{1_2} : the linear model is statistically significant (Fcritic>F_{0.05,n1,n2} which is equivalent to Sig.F<0.05).

where

Given the fact that the analysed data series are time series, in the model (5) the b coefficient (the slope of the regression line), within the conducted analyses stands for the value of the annual average score of the y variable (the primary production of natural gas). The testing of its statistical significance was carried out through the determination of the test statistic:

$$\mathbf{t}_{c} = \frac{\mathbf{b}}{\mathbf{s}_{b}}, \ \mathbf{s}_{b} = \sqrt{\frac{\sum_{i=1}^{n} (\mathbf{y}_{i} - \hat{\mathbf{y}}_{i})^{2}}{n - k - 1}} / \frac{\sum_{i=1}^{n} (\mathbf{x}_{i} - \mathbf{x})^{2}}{n - k - 1}$$
(7)

Taking into account the fact that model (5), which was used for the analysis of the time series, is one factorial, hence in relations (6) and (7) k=1.

The SPSS [4] and Excel [5] (the Data Analysis module) were used for data processing and analysis.

III. RESULTS AND DISCUSSIONS

In order to characterise the evolutions of primarily natural gas productions, both the evolutions of the means recorded in the two groups of states and the evolutions within each group were recorded.

Characteristics of the evolution of average primary productions of natural gas at group level

The first group consists of the 18 EU-28 states where the primary production of natural gas, in the period subjected to analysis, was higher than 0, and the second group includes Norway, Albania, Serbia, Turkey and Ukraine.

From 2003 to 2014 the primary production of natural gas in the EU dropped with an annual average rate of 4.75%, from 201618.3 thousand tonnes of oil equivalent in 2003, to 117985.5 thousand tonnes of oil equivalent. During the 12 years of the analysed period, except for 2004, 2008 and 2010 when a small increase of 0.5% in 2008 as compared to 2007 and to 1.69% in 2010 as compared to 2009 was recorded, there was a constant decrease. The most significant reductions were recorded in 2009 (8.8%), 2011 (11.31%) and in 2014 (10.5%).

During the period subjected to analysis, the average primary production of natural gas was of 163689.16 thousand tonnes of oil equivalent, with a standard deviation of 27289.02 thousand tonnes of oil. Taking into consideration that the confidence interval for the mean, for a Confidence level of 95% ($\alpha = 0.05$), is between 145579.44 thousand tonnes of oil equivalent and 181798.88 thousand tonnes of oil equivalent therefore the null hypothesis H_{0_1} is rejected and the alterative hypothesis H_{1 1} is accepted, consequently the mean is statistically significant. Moreover, as the value of the coefficient of determination is 16.67% it grants an adequate representability. During the same period, in the five non-EU countries considered, there was an evolution with slight oscillations around an increasing trend, thus the average annual growth rate of the primary production of natural gas was of 2.62%. It is worth noting that, although their entire production was by 32.96% higher in 2014 than in 2003, the maximum volume of production of 111520.3 thousand tonnes of oil equivalent had been recorded in 2010 (33.73% higher than in 2003).

For the non-EU states, the mean of the analysed period was of 102459.11 thousand tonnes of oil equivalent (37.41% lower than the average production in the EU), with a standard deviation of 10500.27 thousand tonnes of oil. The confidence interval for the mean, for a Confidence level of 95% (α =0.05) was between 95490.85 thousand tonnes of oil equivalent and 109427.37 thousand tonnes of oil equivalent.

Consequently the null hypothesis $H_{0_{-1}}$ is rejected and the alternative hypothesis $H_{1_{-1}}$ is accepted, hence the mean of the total primary production of natural gas in all the five countries is statistically significant. Considering that, in this particular case, the value of the coefficient of determination is 10.25% hence it results that the value of the mean provides a very good representability.

In order to emphasise, on the one hand, the tendencies of the volume of natural gas primary production in the two state groups, as well as for a better comparability between them, departing from their empirical values, two series of normative variables were generated by means of the (X) transformation. The resulting data series are graphically represented in figure 1. Also, the characteristics of the evolution trends of the two series are presented in table I.

Considering that for the chosen significance threshold α =0.05 its values are much lower than α both for the EU-28 group and for the non-EU group, the null hypothesis H_{0_2} is rejected and the alternative hypothesis H_{1_2} is accepted, thus both regression models are statistically significant. The values of their parameters are also statistically significant (by taking into account the P_value, the H_{1_2} hypotheses are accepted).

A conclusion that can be drawn from the analysis of the trajectories of evolution within the two groups is that the tendency towards the decrease of the primary production of natural gas in EU-28 is more prominent than the growth tendency of the primary production of natural gas within the non-EU group (|-0.2863| > |0.2659|).

Characteristics of the evolution of primary productions of natural gas within groups

Although the general trend of natural gas production at EU level, characterised by the evolution of annual means, has been a descending one, there are countries such as Bulgaria, Check Republic and Poland, as well as states where the production decrease rate has been considerably lower than in the EU-28. They have been, however, counterbalanced by the reductions recorded by countries with a significant weight within the total production of the EU.

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Departing from this observation, according to the volume of primary production of natural gas, the 18 states forming the EU group have been organised into five clusters (table II). Their weights in the total primary production of natural gas from 2003 and 2008 in the EU-28 are presented in figure 2. A concise analysis of the structural modifications according to the weight of the

five clusters regarding the primary production of natural gas in the EU-28 highlights the fact that, as compared to 2003, in 2014 the C1, C4 and C5 clusters recorded a total decrease of 1.45 percentage points which led to an increase in the weight of clusters C2 (+0.26 percentage points) and C3 (+1.19 percentage points).



Fig.1.The directions of the evolution of natural gas primary production in the EU-28 groups of states and in the non-EU states, from 2003 to 2014 (normative data series). Source: devised by the authors

TABLE I									
Coefficients		P_value	Confidence level 95%		Sig.F	Multiple R	R Square		
		_	Lower	Upper					
a	1.5751	7.58E-09	1.3753	1.7747	1.49E-09	0.98858	0.97724		
b	-0.2863	1.5E-09	-0.3171	-0.2556					
а	-1.4629	0.0001	-1.9879	-0.9378	2.51E-05	0.91818	0.84307		
b	0.2659	2.51E-05	0.1851	0.3468					
	a b a b	Coefficients a 1.5751 b -0.2863 a -1.4629 b 0.2659	Coefficients P_value a 1.5751 7.58E-09 b -0.2863 1.5E-09 a -1.4629 0.0001 b 0.2659 2.51E-05	Coefficients P_value Confidence la a 1.5751 7.58E-09 1.3753 b -0.2863 1.5E-09 -0.3171 a -1.4629 0.0001 -1.9879 b 0.2659 2.51E-05 0.1851	TABLE I Coefficients P_value Confidence level 95% Lower Upper a 1.5751 7.58E-09 1.3753 1.7747 b -0.2863 1.5E-09 -0.3171 -0.2556 a -1.4629 0.0001 -1.9879 -0.9378 b 0.2659 2.51E-05 0.1851 0.3468	TABLE I Coefficients P_value Confidence level 95% Sig.F Lower Upper a 1.5751 7.58E-09 1.3753 1.7747 1.49E-09 b -0.2863 1.5E-09 -0.3171 -0.2556 2.51E-05 a -1.4629 0.0001 -1.9879 -0.9378 2.51E-05 b 0.2659 2.51E-05 0.1851 0.3468 2.51E-05	TABLE I Coefficients P_value Confidence level 95% Sig.F Multiple R Lower Upper a 1.5751 7.58E-09 1.3753 1.7747 1.49E-09 0.98858 b -0.2863 1.5E-09 -0.3171 -0.2556 0.91818 a -1.4629 0.0001 -1.9879 -0.9378 2.51E-05 0.91818 b 0.2659 2.51E-05 0.1851 0.3468 0.91818 0.91818		

Source: devised by the authors

TABLE II

THE STRUCTURE OF THE EU GROUP CLUSTERS ACCORDING TO THE VOLUME OF PRIMARY PRODUCTIONS OF NATURAL GAS FROM 2003 TO 2008

Cluster	Ν	States included in the cluster
C1	2	Netherlands, Great Britain
C2	4	Denmark, Germany, Italy, Romania
C3	5	France, Croatia, Hungary, Austria, Poland
C4	5	Bulgaria, Check Republic, Ireland, Spain, Slovakia
C5	2	Greece, Slovenia

Source: devised by the authors

The total production from the first cluster (C1) in 2003 amounted to 71.84% and in 2014 it reached 70.41% of the total primary production of natural gas from the EU-28. Essentially, during the analysed period, the evolutions of the primary production of natural gas in the Netherlands and Great Britain had a tremendous impact on the volume of production of this resource at EU level. Although their weight in the total production of 2014 was inferior to the one of 2003 by only 1.43 percentage points, the modifications are significant in absolute values. Hence (figure 3) while the primary production of natural gas in the Netherlands oscillated around an approximately steady trend (with an annual average rate of -0.37%), which led to an almost insignificant decrease of production from 52212.1 thousand tonnes of oil equivalent in 2003 to 50144.4 thousand tonnes of oil

equivalent in 2014 (a decrease of 3.96 percentage points), in Great Britain the primary production of natural gas fluctuated by an average of 8.97%. This rate led to the decrease of the average production in cluster C1 from 92633.5 thousand tonnes of oil equivalent in 2003 to 32930.8 thousand tonnes of oil equivalent in 2014 (a decrease of 64.45 percentage points).

From 2003 to 2014, in the C1 cluster there was an annual decrease of approximately 4.93% in the average primary production of natural gas. In absolute figures the production was reduced from 72422.8 thousand tonnes of oil equivalent in 2003 to only 41537.6 thousand tonnes of oil equivalent in 2014. Bearing in mind the weight of this cluster within the total primary production of natural gas in the EU-28, the impact on it was significant as it led to a decrease of production by 61770.4 thousand tonnes of oil equivalent.

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Fig.2. The weight of the clusters' production in the primary production of natural gas in the EU-28 from 2013 to 2014. Source: devised by the authors



Fig. 3. The evolutions of the primary production of natural gas (in thousands of tonnes of oil equivalent) in the states included in cluster C1. Source: devised by the authors.



Fig. 4 The evolutions of the primary production of natural gas (in thousands of tonnes of oil equivalent) in the states included in cluster C2. Source: devised by the authors.

Cluster C2 included Denmark, Germany, Italy, Romania and, in 2003, it had a weight of 22.28% from the total primary production of natural gas at EU-28 level. During the surveyed period, this weight increased by 0.26 percentage points, still ranking second, at a great distance both from C1 and from C3.

Similarly to the C1 cluster, in absolute figures, the primary production of natural gas dropped significantly in cluster C2 (Figure 4). Although for short periods of time there was an increase of production, specifically in Denmark, from 2003 to 2005, from 7202.5 to 9383.5 thousand tonnes of oil equivalent and in Germany

between 2005 and 2007, from 14333.8 to 14858.9 thousand tonnes of oil equivalent, the trend was one of decline of production at cluster level.

In the cluster, the average primary production of natural gas dropped from 11231.5 thousand tonnes of oil equivalent in 2003 to 6649.7 thousand tonnes of oil equivalent (a 47.79% decline). In the surveyed period, the annual rate of decrease in production in the states of the C2 cluster was between 1.57% in Romania and 6.25% in Germany, amounting to 4.65% in this cluster, only 0.28 percentage points lower than in cluster C1.



Fig. 5 The evolutions of the primary production of natural gas (in thousands of tonnes of oil equivalent) in the states included in cluster C3. Source: devised by the authors

Another characteristic of the C2 cluster is the tendency towards convergence of the primary productions of natural gas around the mean. If in 2003 the difference between the highest production (Germany - 15923.0 thousand tonnes of oil equivalent) and the lowest (Denmark - 7202.5 thousand tonnes of oil equivalent) was of 8720.5 thousand tonnes of oil equivalent, in 2014 it was reduced to 4618.0 thousand tonnes of oil equivalent (a 47.1% decrease).

On the other hand, the modifications brought about from 2003 to 2004 in the primary productions of natural gas in the four countries from the C2 cluster, led to a change in their weight within the total production at the cluster level. Hence, if in 2003 Germany ranked first with 35.44%, followed by Italy (25.31%), Romania (23.21%) and Denmark(16.04%), in 2014 Romania ranked first with 32.95%, followed by Germany (29.44%), Italy (22.02%) and Denmark (15.59).

Another characteristic of the C2 cluster is the fact that, in absolute figures the production declined from 44925.8 thousand tonnes of oil equivalent in 2003, to 26598.6 thousand tonnes of oil equivalent in 2014, which represents a 18327.2 thousand tonnes of oil equivalent decrease, which although is around three times smaller than the production decrease recorded in cluster C1, has an equally significant contribution to the decline of the primary production of natural gas in the EU-28.

Cluster C3 includes France, Croatia, Hungary, Austria and Poland. The average primary productions of natural gas in the states comprised in this cluster, in the surveyed period of time, were much lower than in the C1 and C2 clusters, ranging between 600 and 3900 thousand tonnes of oil equivalent.

As compared to the C1 and C2 clusters, the C3 cluster, apart from the differences regarding the volume of the primary productions of natural gas, displays some particularities. One is connected to the values of the annual average rates recorded in the five states. With the exception of France where the annual average evolution

rate of the primary production of natural gas is of -13.82%, in the other states it ranges between -4. 46% in Austria and +0,28% in Poland.

Another feature is linked to the divergent process of the evolution of productions within the states pertaining to this cluster. Hence, if in 2003 the difference between the highest (Poland: 36113.3 thousand tonnes of oil equivalent) and the lowest (France: 1281.6 thousand tonnes of oil equivalent) was of 2329.7 thousand tonnes of oil equivalent, in 2014 it reached 3533.8 thousand tonnes of oil equivalent (1.52 times greater).

On the other hand, because of the massive decline in the primary production of natural gas starting from 2007 onwards, France had to leave the C3 cluster in 2014 and, as a result of its very low production value, it joined cluster C5.

In absolute values, at the C3 cluster level, production dropped from 10760.8 thousand tonnes of oil equivalent in 2003, to 7704.8 thousand tonnes of oil equivalent in 2014, which represents a 3056.0 thousand tonnes of oil equivalent decrease.

Clusters C4 and C5 are characterised by primary productions of natural gas which amount to less than 1% of the total EU-28 production. It is worth mentioning that in the C4 cluster, in the period subjected to analysis, the primary production of natural gas recorded a 61.63% increase in the Check Republic, whereas in Bulgaria the increase was more than ten times larger. However, the increase was negative (-425.0 thousand tonnes of oil equivalent) in the cluster.

In cluster C5, the primary production of natural gas decreased both in Greece and in Slovenia, the total reduction amounting to 27.3 thousand tonnes of oil equivalent. Norway, Ukraine, Albania, Serbia and Turkey are part of the surveyed non-EU group of states. As the evolutions of the primary productions of natural gas in these countries differ significantly from one state to the other and due to their small number, they have not been included into clusters.

GROUP										
Country	Mean	Conf. level 95%		V (%)	Sig. F	Increase	Conf. level 95%			
		Min	Max				Min	Max		
Norway	85379.5	78067.5	92619.6	13.48	1.5E-05	2958.1	2113.2	3802.9		
Ukraine	16164.8	15626.2	16702.9	40.61	0.00822	-169.2	-54.5	-284.0		
Albania	11.7	8.8	14.9	31.31	0.02313	0.86	0.15	1.58		
Serbia	303.5	243.1	363.9	23.17	0.00471	19.9	7.6	32.1		
Turkey	599.4	511.2	687.6	5.24	0.16049	-16.7*	-31.7*	-1.6*		

TABLE III THE CHARACTERISTIC VALUES FOR THE MEANS AND FOR THE ANNUAL GENERAL SCORES OF THE PRIMARY PRODUCTION OF NATURAL GAS (IN THOUSANDS OF TONNES OF OIL EQUIVALENT) RECORDED FROM 2003 TO 2014 IN THE NON-EU FIVE STATE

*The computed values correspond to a Confidence level of 80% (α =0.2); Source: devised by the authors.

In order to identify the particularities and to characterize the evolution of production within these states, on the one hand, the average productions and their confidence interval for a Confidence level of 95% (α =0.05) as well as the coefficients of variation for the means were established and, on the other hand, departing from the regression models corresponding to the evolution of individual productions, the annual average scores (the slope of the regression line) as well as their corresponding confidence intervals were determined. The results obtained are presented in table III.

IV. CONCLUSIONS

From the analysis of the limits of the confidence intervals for the means of natural gas primary productions, it results that the null hypothesis $H_{0_{-1}}$ is rejected and the alternative hypothesis $H_{1_{-1}}$ is accepted therefore the means' values are statistically significant.

Considering the values of the coefficient of variation (V), it results that, for Norway and Turkey, the mean values offer a consistent representability, with regard to the means of Albania and Serbia, the representability is adequate, and for Ukraine, the representability of the mean is lower but it can still be taken into consideration. In order to establish the evolution trends, we determined the parameters of the linear regression model in which the slope of the regression line represents the average annual score of the primary production of natural gas within the respective states.

With regard to Turkey, for the Confidence level of 95%, the null hypothesis H0_2 is accepted. For this country, the values of the annual average score and the values of the limits of its corresponding confidence interval - these values have all been illustrated in table III - are statistically significant for the Confidence level of 80% (α =0.2). From the data presented in table III, with a probability of 95%, it results that Norway's primary production of natural gas in the period subjected to analysis, grew by an annual average amount of 2958.1 thousand tonnes of oil equivalent, the limits of the

confidence interval being equal to 2113.2 and 3802.9 thousand tonnes of oil equivalent, respectively.

Also, in the analysed period, there was an increase in the primary production of natural gas in Albania (by 0.86 thousand tonnes of oil equivalent annually) and in Serbia where the average annual score was of 19.9 thousand tonnes of oil equivalent, within a confidence interval between 7.6 and 32.1 thousand tonnes of oil equivalent.

On the other hand, in Ukraine during the analysed period, there was a decline in the primary production of natural gas. The annual average score was around -169.2 thousand tonnes of oil equivalent, in a confidence interval ranging between -284.0 and -54.5 thousand toe.

With regard to Turkey, the annual score of the primary production of natural gas amounting to -16.7 thousand tonnes of oil equivalent can be accepted with a probability of only 80%. This is due to the massive increase of the primary production of natural gas from 461.0 thousand tonnes of oil equivalent in 2003 to 837.6 thousand tonnes of oil equivalent in 2008, followed by a significant decline up to 2014 when it amounted to only 394.6 thousand tonnes of oil equivalent. Such an evolution can be analysed by either departing from a 2^{nd} order polynomial trend-line or by conducting a separate analysis of the evolution of production for the two periods taken.

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