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Convergence of energy efficiency policy in Ukraine and developed countries: the causal relationship between key determinants[2]

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Abstract: The unbalanced and unsynchronised ecological, energy, and economic policies of Ukraine provoke the dilemma on the priority of the new trajectory of the country's development and achievement of Sustainable Development Goals in energy-saving and increasing energy efficiency. Thus, the exacerbation of environmental conflicts, a huge energy consumption level, and increasing greenhouse gas emissions requires developing effective mechanisms to overcome and eliminate the mentioned issues. It should be realised with the simultaneous increase in the country's energy security. The paper aimed to check the convergence of the energy efficiency policy in Ukraine and developed countries. For the assessment of the energy policy efficiency, the study used the core indicators of The Energy Trilemma Index, which grouped by the three vectors: energy security; energy equity, environmental sustainability. The investigation object was Ukraine and EU developed countries (Lithuania, Latvia, Poland, Croatia). These countries have two mutual characteristics: in the years 1990-1992 the aforementioned countries started political transformations from refusing the monopoly of the Communist Party; in economic terms – the transition from centralised governance to the market economy. The time for analysis – the years 2000-2020; the dataset was obtained from the following databases: World Bank, Eurostat and Ukrstat. The study applied the σ-convergence and β-convergence for the analysis. The empirical results confirmed that reorientation of the Ukrainian energy sector based on implementing the instruments for declining the energy gaps could be the core drivers to synchronise the national energy policy with strategic targets under Sustainable Development Goals. Besides, it requires using cost-effective, innovative energy technologies and developing new options for the country's sustainable energy development. The study's findings could be applicable in resolving the contradictions in implementing the Ukrainian energy policy.

Keywords: energy policy, energy gap, energy efficiency, sustainable development.

JEL: P18; P28; P48; Q43; Q48

Introduction

In December 2019, the European Commission declared the updated European climate policy, "European Green Deal" [COP25 Summary Report 2019]. According to the document, the EU countries will reduce the emissions of polluters in the air to zero by 2050 [Financing 2020] with simultaneous increasing of the share of renewable energy in the energy balance. Ukraine has accepted the EU vector of future development. It aims to synchronise all Ukrainian policies, involving energy policy with the strategic orienteers in the EU on the transition to a circular and carbon-free economy. The snowballing growth of the demand on energy sources

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(consider the official report of World Energy Council [WORLD 2020]) suggesting that the global energy consumption in 2030 could increase by 55% compared to 2020, provokes changes in the structure of the country's energy balance. Thus, as other EU oriented countries, Ukraine should develop and implement a balanced policy on synchronising the national energy policy with the European one.

Theoretical premises

The scientific community has already accumulated a huge scientific background on evaluating the efficiency of national strategy energy development. Thus, in the paper [Zhang et al., 2011] analysed China's evolution and the USA's energy strategies based on Bai and Perron test. Jensen L. and Sperling K. [Jensen & Sperling, 2019] improved the "Danish approach" by considering the strategic energy planning. Siksnelyte et al. [Siksnelyte et al. 2019] estimated the efficiency of the implemented actions on energy sustainability using the Multi-Objective Optimisation MULTIMOORA.

Huge scientific results have already existed on identification the economic [Akimova et al., 2017; Ibragimov, 2019a], social [Kwilinski et al., 2020a; Vasylieva et al., 2019; Kharazishvili et al., 2020; Borychowski et al., 2020], political [Ziabina & Pimonenko, 2020; Dalevska et al., 2019; Dementyev&Kwilinski, 2020], financial [Pimonenko et al., 2017b; Sotnyk et al., 2018; Vasylieva et al., 2018; Rubanov et al., 2019; Bilan et al., 2019a; Pająk, et al., 2016; Kaźmierczyk & Chinalska, 2018], investment [Lipkova & Braga, 2016; Kendiukhov & Tvaronavičienė, 2017; Ibragimov, 2019b; Kasztelnik & Gaines, 2019; Lyeonov et al., 2019], technological [Pimonenko et al., 2017a, Kwilinski 2018; Miskiewicz 2020; Kwilinski et al., 2020b; Akimov et al., 2020; Bogachov et al., 2020; Chygryn et al., 2020; Czyżewski et al., 2019; 2020; Dzwigol&Dźwigoł-Barosz, 2018; 2020; Dzwigol, 2019; 2020; Dzwigol et al., 2020; Kuzior et al., 2020; Kwilinski et al., 2019; Lyulyov et al., 2020; Miskiewicz, 2020; Saługa et al., 2020; Savchenko et al., 2019; Tkachenko et al., 2019a; 2019b; 2019c], marketing [Akhundova et al. 2020], ecological [Chygryn & Krasniak 2015; Cebula et al. 2018; Dkhili 2018; Pimonenko, 2019; Pavlyk 2020; Kyrylov et al., 2020] determinants in providing the energy efficiency of the national economy. The world scientific community has investigated the approaches to assessing and forecasting energy efficiency gaps, principals, and instruments to implement the government policy to minimise energy efficiency gaps. Thus, some authors [Gerarden et al., 2017; Stadelmann, 2017] allocated four core factors which provoked the energy efficiency gaps: market failures, multi-vector interests of stakeholders, valuation errors, minimisation of energy efficiency costs. Labanca P. [Labanca, 2018] defined energy systems as social and technical logical systems, where the energy technologies' improvement provoked social practices, values, relationships, and institutions. The scientists in the paper by Mardani et al. [2017] used the DEA method to assess the energy efficiency gaps under energy efficiency projects' implementation. VakulenkoI and MyroshnychenkoIu [Vakulenko & Myroshnychenko, 2015] highlighted the drivers of increasing energy efficiency in Ukraine under the investment limitation.

The scientists used empirical data to identify the cause of unbalanced energy development and justify increasing its energy efficiency. The methodological base for the estimation was the concept of σ- and β-convergence. The indicators of variation in the energy efficiency level for the countries' applied for the assessment of σ-convergence. At the same time, β-convergence based on the hypothesis that the countries' stationarity characteristics were similar, or the countries had the same trajectory of sustainable growth. Thus, the authors in the paper by Han et al. [2018] analysed the impact of trade integration and the regional cooperation on the energy convergence in 89 countries participating in the Belt and Road initiative. They found that σ- and β-convergence for 2000-2014 confirmed the statistically significant and positive impact of trade integration on the countries' energy-effective cointegration, particularly with low- and middle-income countries. A similar conclusion was made by Qi et al. [2019] for 59 countries included in Belt and Road initiative. The findings confirmed that the higher level of energy intensity's convergence was in countries with a high level of bilateral trade and imports of technological and innovative equipment from China than others. Using the stochastic convergence models for 27 OECD countries during the 1980–2014 years, Bulut U. and Durusu-Ciftci D. [Bulut&Durusu-Ciftci, 2018] proved the lack of convergence to the average level of energy intensities in the OECD of the following countries: Iceland, South Korea, USA, Mexico, Chile. It requires the providing of energy efficiency policy through providing of the implementation of innovations and compliance with the international environmental agreements. Apergis N. and Christou C. [Apergis&Christou, 2016], using the convergence club algorithm for 31 countries for 1972–2012, allowed concluding that the energy productivity convergence for all analysed countries has not existed.

Most investigations used the integrated energy efficiency indicators (energy use/consumption intensity, energy productivity, energy intensity, etc.) to assess σ- and β-convergence. Simultaneously, the snowballing negative consequences from ecological contradictions, increasing energy consumption in countries, and the growth of greenhouse gas emissions require the development of mechanisms for solving and eliminating the issues mentioned above to increase energy security. It should be noted that estimation of the convergence between ecological, social and economic development of the country allowed eliminating the dilemmas of indicating how to achieve the Sustainable Development Goals in energy efficiency and energy saving. In this direction, the World Energy Council developed the concept «Energy Trilemma», which allowed accepting the justified decisions to balance energy security; energy equity, and environmental sustainability [World Energy Council 2020; Pająk et al., 2017]. Therefore, the balance was estimated by the World Energy Trilemma Index. Considering the official report 2019, nine out of ten countries-leaders in the rating were European countries (Switzerland, Sweden, Denmark, the United Kingdom, Finland, France, Austria, Luxembourg, Germany, New Zealand). It was a result of the balanced EU energy policy: developing the single energy infrastructure in EU (Treaty on European Union, Maastricht), providing Directives EU №2012/27/EU "The energy efficiency" and №2014/94/EU "On the deployment of alternative fuels infrastructure", recommendations, EU Commission № 2012/148/EU "The preparations for the roll-out of smart metering systems", The Strategic Energy Technology (SET), climate strategy «Green Deal Policy», etc. The EU vector of the Ukrainian national economy's development required the synchronisation of government policy involving providing energy efficiency.

The paper aimed to estimate: the level of asynchrony of the state energy policy of Ukraine with European practices of energy efficiency strategy implementation based on the World Energy Trilemma Index and concept of σ-convergence; the responsiveness to national policy changes to European standards regulating energy development using the concept of β-convergence.

Methodology

In the methodological basis for the analysis the authors used σ- and β-convergence. Considering the papers of Han et al. [2018] and Qi et al. [2019] for the σ-convergence's assessment, the study used the standard deviation across countries *i* in time *t*:

(1)
$$\sigma_t = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(lnTR_{jit} - \overline{lnTR_{jit}})^2}$$

деTR – Energy Trilemma subindexes j :energy security, energy equity, environmental sustainability;

N– number of countries;

i – country;

t – time.

Thus, considering the concept if the standard deviation declined, the σ-convergence observed between countries, in the other case – divergence.

The study used the regression equation for the assessment of β-convergence:

(2)
$$ln(\frac{TR_{jit}}{TR_{jit-1}}) = \alpha + \theta \ln\left(TR_{jit-1}\right) + \phi X_{it} + \varepsilon$$

where X – matrix of additional endogenous variables which indicated the country's features and all owed saving the stationarity of the variables at the same level;

α, θ, ϕ – calculated variables;

ε – error term.

If θ was less than zero, the convergence existed for selected parameters. The parameters' absolute value characterises the relationship between the beginning level of energy efficiency and its growth rate. The β value indicated convergence speed, the percentage of distance that achieved long-term energy efficiency equilibrium by the country in one time.

The exogenous variables were globalisation index (KOF) and trade openness (Trade). Considering the authors' conclusions in the papers by Cole [2006], Bilan et al. [2019b] Kostiukevych et al. [2020], Panchenko et al. [2020], adn Lyulyov et al. [2021], the globalisation process indicated the trend of country's economic development, and trade liberalisation led to increasing energy usage per capita.

The object of the investigation was Ukraine, and for comparison, the study selected 4 EU countries (Lithuania, Latvia, Poland, Croatia) which had similar characteristics in: political transformation (1990-1992) from rejecting the monopoly of the Communist Party; economy – the transition from centralised management to a market economy. The core indicators of the countries selected for analysis are presented in Table 1.

Table 1. The explanation of variables

Variables	**Abbreviations**	**Source**
Energy Security	ES	World Energy Council
Energy Equity	EE	World Energy Council
Environmental Sustainability	ESus	World Energy Council
Globalisation Index	KOF	KOF Swiss EconomicInstitute
Trade (% of GDP)	Trade	World Data Bank

Source: own work

The descriptive statistics of the selected variables is presented in Table 2.

Table 2. The descriptive statistics of EE, ES, ESus, KOF, Trade for the selected countries, 2014-2020

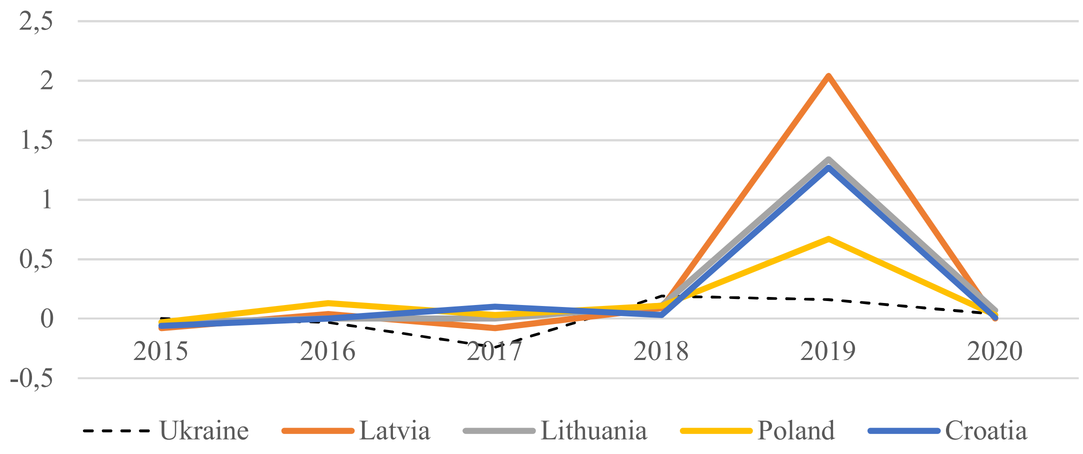
	Country	**Mean**	**Median**	**Maximum**	**Minimum**	**Std.Dev.**	**Skewness**	**Kurtosis**
EE	Ukraine	119.64	116.70	126.80	115.50	4.61	0.54	1.63
	Latvia	103.47	102.80	105.90	102.00	1.62	0.73	1.82
	Lithuania	103.86	100.90	113.10	99.50	6.31	0.92	1.89
	Poland	101.49	101.50	101.90	100.90	0.33	-0.59	2.54
	Croatia	96.70	96.50	98.00	95.90	0.69	0.96	2.91
ES	Ukraine	119.59	118.00	125.60	113.30	4.61	0.16	1.72
	Latvia	137.57	139.20	141.50	126.10	5.29	-1.70	4.41
	Lithuanian	110.54	114.60	117.10	89.80	10.02	-1.48	3.68
	Poland	112.99	113.50	114.80	109.00	1.97	-1.26	3.48
	Croatia	120.67	122.00	123.80	110.30	4.63	-1.93	4.93
ESus	Ukraine	119.79	122.00	127.60	110.70	6.55	-0.29	1.67
	Latvia	101.10	100.50	104.60	96.70	2.69	-0.24	2.18
	Lithuanian	98.79	99.20	103.10	93.30	3.35	-0.41	2.12
	Poland	117.83	118.20	120.00	114.30	2.05	-0.59	2.19
	Croatia	109.99	109.30	114.10	107.40	2.63	0.41	1.67
KOF	Ukraine	74.99	74.95	76.62	73.38	1.13	0.06	1.98
	Latvia	79.06	79.42	82.71	75.22	2.82	-0.26	1.81
	Lithuanian	80.84	80.89	82.94	78.83	1.43	0.11	1.93
	Poland	81.00	80.40	83.57	79.67	1.57	0.87	2.00
	Croatia	81.18	80.08	84.32	79.52	1.96	0.78	1.89
Tra	Ukraine	100.34	100.69	107.08	95.15	4.66	0.21	1.57
	Latvia	126.43	122.93	135.88	119.19	6.55	0.37	1.49

	Lithuanian	164.57	160.60	181.90	147.61	12.90	0.06	1.59
	Poland	101.86	102.79	109.20	93.73	5.58	-0.23	1.83
	Croatia	93.79	93.48	100.36	88.70	3.55	0.59	3.12

Source: own work

The findings in Table 2 allowed concluding that Ukraine, among selected countries, had a better position on the average value of the subindexes Energy Equity (119.64) and Environmental Sustainability (119.79). At the same time, the Skewness of the subindex Environmental Sustainability was negative (-0,29). It means that the average value could not paint the real picture of the country's development. All indicators had a positive Kurtosis for Ukraine, which confirmed that the analysed variables were possibly leptokurtic in form. Latvia had the highest average value of the subindex Energy Security (137.57). The standard deviation of variables for all countries was less than 10%, which meant a weak variability of objects' features. It should be noted that among analysed countries, Ukraine had been the leader on Energy Trilemma Index (66.00) before 2019. However, the EU countries had been demonstrating an increase of the Energy Trilemma Index since 2019 (Fig. 1)

Figure 1. The growth rate of Energy Trilemma Index for analysed countries, 2014-2020.



Sources: compiled by the authors.

Results

Considering the abovementioned methodology, at the first stage, the study estimated the σ-convergence. The findings of the σ-convergence assessment are presented in Table 3.

Table 3. The empirical justification of σ-convergence between variables for selected countries

σ-convergence	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
	For subindex energy security						
without Ukraine	0.21	0.02	0.04	0.05	0.05	0.05	0.04
with Ukraine	0.22	0.03	0.05	0.07	0.07	0.02	0.03
	for subindex energy equity						
without Ukraine	0.01	0.01	0.02	0.02	0.02	0.05	0.04
with Ukraine	0.01	0.01	0.01	0.03	0.02	0.03	0.02
	for subindex environmental sustainability						
without Ukraine	0.03	0.01	0.04	0.01	0.01	0.03	0.04
with Ukraine	0.06	0.04	0.03	0.01	0.02	0.05	0.01

Sources: own work

The declining of the standard deviation of natural logarithms of subindexes Energy Security and Environmental Sustainability confirmed that the countries' government-oriented cooperation mechanism focused on the achievement of the process convergence in energy security and environmental sustainability. Simultaneously, during the years 2014-2020, for the selected countries, the standard deviation of the natural logarithms of the subindex Energy Equity increased. It justified the strengthening of cooperation on increasing the energy efficiency of the countries.

The confirmation of the σ-convergence allowed checking hypothesis on β-convergence between processes for the selected countries. At the next stage, the stationarity of the selected variables was indicated for β-convergence assessment. The findings of the panel unit root test are presented in Table 4.

Table 4. The findings of stationarity analysis using the panel unit root test

Statistics (p-value)		Levin, Lin & Chu	Hadri	ADF-Fisher Chi-square	PP-Fisher Chi-square
ln(EE_{t-1})	at level	-56.37 (0.00)	3.14 (0.00)	6.58 (0.76)	9.22 (0.51)
	at 1st difference	-23.61 (0.00)	1.69 (0.04)	31.86 (0.00)	23.45 (0.01)
ln($\frac{EE_t}{EE_{t-1}}$)	at level	-23.98 (0.00)	1.69 (0.04)	31.94 (0.00)	23.36 (0.01)
	at 1st difference	-21.78 (0.00)	4.37 (0.00)	35.79 (0.00)	39.68 (0.00)
ln(ES_{t-1})	at level	-4.11 (0.00)	2.89 (0.00)	14.52 (0.15)	1.67 (0.99)
	at 1st difference	-10.09 (0.00)	3.77 (0.00)	47.49 (0.00)	65.98 (0.00)
ln($\frac{ES_t}{ES_{t-1}}$)	at level	-10.13 (0.00)	3.76 (0.00)	47.50 (0.00)	66.02 (0.00)
	at 1st difference	-8.36 (0.00)	2.61 (0.00)	49.65 (0.00)	68.34 (0.00)
ln($ESus_{t-1}$)	at level	0.01 (0.51)	3.46 (0.00)	14.04 (0.17)	6.71 (0.75)
	at 1st difference	-4.00 (0.00)	3.03 (0.00)	26.13 (0.00)	31.38 (0.00)
ln($\frac{ESus_t}{ESus_{t-1}}$)	at level	-4.00 (0.00)	3.03 (0.00)	26.14 (0.00)	31.42 (0.00)
	at 1st difference	-2.14 (0.00)	4.84 (0.00)	28.76 (0.00)	38.20 (0.00)
lnKOF	at level	4.68 (1.00)	4.00 (0.00)	3.21 (0.97)	0.09 (1.00)
	at 1st difference	-1.52 (0.06)	4.04 (0.00)	17.06 (0.07)	17.02 (0.06)
lnTrade	at level	0.20 (0.58)	2.98 (0.00)	7.87 (0.64)	2.65 (0.98)
	at 1st difference	-2.85 (0.00)	2.03 (0.02)	16.35 (0.03)	27.09 (0.00)

Source: own work

An analysis of the stationarity of time series at the level confirmed that for ln (EE_{t-1}) (tests ADF-Fisher Chi-square, PP-Fisher Chi-square), ln(ES_{t-1}) (teats ADF-Fisher Chi-square, PP-Fisher Chi-square), ln($ESus_{t-1}$) (tests Levin, Lin & Chu, ADF-Fisher Chi-square, PP-Fisher Chi-square), lnKOF (tests Levin, Lin & Chu, ADF-Fisher Chi-square, PP-Fisher Chi-square), lnTrade (тести Levin, Lin & Chu, ADF-Fisher Chi-square, PP-Fisher Chi-square) the absolute values of τ-statistic are less than the absolute values of minimal value at 1 %, 5 % and 10 % significance. It did not allow rejecting the null hypothesis on exitance unit root in the time series at the level. The minimal probability that time series had the unit root test and non-stationary was 49% (p-value>10 %). At the same time, the findings of Levin, Lin & Chu, Hadri, ADF-Fisher Chi-square, PP-Fisher Chi-square tests for all variables at the first level confirmed the stationarity of the modified variables. Therefore, the time series at the first level was stationary.

The findings of β-convergence's assessment are presented in Table 5.

Table 5. The finding of the β-convergenceanalysis

	ln($\frac{EE_t}{EE_{t-1}}$)	**ln($\frac{ES_t}{ES_{t-1}}$)**	**ln($\frac{ESus_t}{ESus_{t-1}}$)**
ln(EE_{t-1})	-0.093 (0.068)	–	–
ln(ES_{t-1})	–	-0.007 (0.033)	–
ln($ESus_{t-1}$)	–	–	-0.147 (0.02)
lnKOF	0.031 (0.08)	-0.04 (0.709)	-0.209 (0.02)
lnTrade	0.029 (0.067)	0.049 (0.234)	0.048 (0.13)

Source: own work

Considering the findings in Table 5, the absolute values of β-convergence changes in the interval from 0.093 (energy security) to 0.147 (environmental sustainability). It confirmed the high convergence between countries on these parameters. The positive, statistically significant impact of globalisation index and trade openness confirmed the possible acceleration of β-convergence for Energy Security. It meant that the growth rate of Energy Security was high at the first stage and then slowed down with the value's increase, and then approached stability. Simultaneously, KOF's and Trade's impact on energy efficiency was not statistically significant, which confirmed that KOF and Trade did not affect the countries' convergence on energy equity. Despite the high absolute coefficient of β-convergence, globalisation processes constrained its acceleration.

Summary, recommendations

The issues regarding the effective use of energy recourses and responsible attitude to the environment had the priority for Ukrainian government, which complied with the Directive 2012/27/EU of the European Parliament and the Council "On energy efficiency" and 2014/94/EU "On the deployment of alternative fuels infrastructure", 2012/148/EU Commission Recommendation "On preparations for the roll-out of smart metering systems", The Strategic Energy Technology (SET), Ukrainian Energy Strategy to 2030 (from 24 July 2013), National strategy on heat supply to 2030. In this case, the transformation of the Ukrainian energy sector should be realised by implementing effective mechanisms to achieve energy efficiency policy's convergence with leading EU countries. Thus, the implementation of modern innovative energy technologies could be a core instrument for overcoming climate change's negative consequences. Besides, it allowed creating new options for the sustainable energy development of the country.

The findings of σ- and β-convergence assessment confirmed the convergence of national to EU energy policies. Simultaneously, the increasing Ukrainian energy efficiency was limited by the huge share of fuel import, involving natural gas and oil, and the high intensity of CO2 emissions.

The huge level of energy infrastructure depreciation restricted the increasing energy efficiency and required additional investment for renovation and modernisation. Besides, the findings of σ-convergence on subindexes Energy Trilemma Index confirmed the necessity to improve the energy sector's legislation, particularly on using renewable energy in the country, example.g, the development of the biogas technologies.

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