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Composite fuel poverty index as a means to assess energy security of the country

Abstract. Introduction. The issues of strengthening Ukraine's energy security are related to addressing the insufficient understating of its essence, nature and criteria for assessing the vulnerability of the national economy. The need to improve the existing methodology for calculating the overall performance of energy security assessment is considered to be relevant due to the insufficient level of research on related issues and inconsistency of individual aspects. The composite fuel poverty index by region provides information on energy efficiency of households in different regions and helps to assess the level of poverty of the regions derived from the analysis of the consumption of fuel and energy resources by households in the regions, the pricing policy in Ukraine's energy market, as well as the income and expenditure level of households. The purpose is to develop a methodology for determining the composite fuel poverty index by region, revealing the principal factors of its formation, and to identify ways of improving the country's social and economic security in the context of energy market deregulation. The results of the study reveal indicators that allow assessing the consumption of fuel and energy resources by households by region in qualitative and quantitative terms, taking into account the nonlinearity of economic processes in the context of economic transformation. The problems relating to the implementation of social and economic policy of the state are revealed in the context of the Ukrainian energy market deregulation. The authors of the research have developed an analytical model of the energy inefficiency of Ukrainian regions, as well as a model for estimating the fuel poverty index of relevant regions (FPI_i) by using the monetary poverty indicator P_i and the energy inefficiency indicator I_{ci}, i.e. the cost of all energy resources consumed by average households of a region calculated as a unit area. In the 2012-2016 period, the fuel poverty index was established in the range from 0.5 to 0.65. However, the index fluctuations are affected to a great extent by increases in prices on fuel and energy resources, with a high value of the index being indicative of a low level of personal income and high expenditures on fuel and energy resources for Ukrainian households. Conclusion. The calculation of the composite fuel poverty index makes it possible to determine the regions with low incomes and high energy consumption with regard to 1 sq.m of household area. The proposed methodology can become an integral part of the analytical assessment of regions' energy security. The calculation results for Ukraine show that the share of fuel and energy costs as part of household costs exceeded 10% of households' income threshold for 2012-2016, resulting in low living standards of the population and hardship in meeting basic needs. Further increase in fuel and energy prices will bring about an increase in social tension.
Keywords: Methodology; Energy Security; Composite Index; Models; Fuel Poverty; Costs; Income; Prices; Fuel and Energy Resources; Energy Inefficiency
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Інтегральний індекс «енергетичної бідності» як засіб оцінки енергетичної безпеки країни

Анотація. У статті розглянуто питання моделювання та діагностики соціально-економічного розвитку та енергетичної безпеки регіонів. Визначено «вузькі» місця енергетичної безпеки країни. Показано можливість адаптації методології інтегрального індексу оцінки енергетичної бідності регіону з метою подолання загроз соціально-економічної безпеки. Запропоновано моделі діагностики рівня енергоефективності та грошової бідності домогосподарств. Визначено напрямки подолання енергетичної бідності в аспекті побудови соціально орієнтованої ринкової економіки України.

Ключові слова: методологія; енергетична безпека; інтегральний індекс; моделі; енергетична бідність; витрати; доходи; ціни; паливно-енергетичні ресурси; енергетична неефективність.

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Интегральный индекс «энергетической бедности» как средство оценки энергетической безопасности страны

Аннотация. В статье рассмотрены вопросы моделирования и диагностики социально-экономического развития и энергетической безопасности регионов. Определены «узкие» места энергетической безопасности страны. Показана возможность адаптации методологии интегрального индекса оценки энергетической бедности региона с целью преодоления угроз социально-экономической безопасности. Предложены модели диагностики уровня энергоэффективности и денежной бедности домохозяйств. Определены направления преодоления энергетической бедности в аспекте построения социально-ориентированной рыночной экономики Украины.

Ключевые слова: методология; экономическая безопасность; интегральный индекс; модели; энергетическая бедность; расходы; доходы; цены; топливно-энергетические ресурсы; энергетическая неэффективность.

1. Introduction

In terms of the Ukrainian economy, the transformational processes are accompanied by the imperfection of functioning mechanisms of the country's energy market, namely the insufficient development of the inner energy potential, which leads to the energy dependence of the national economy. The use of outdated technologies, triggered the energy inefficiency in the industrial and domestic sectors.

The low level of real personal income indicates the ineffectiveness of the country's social policies, which poses threats to its social and economic security which is based on the qualitative characteristics of the national economic system and should be able to maintain normal living conditions, as well as to ensure sustainable provision of resources for the development of various types of economic activities and observance of national interests to the advantage of the public.

It is commonly known that an untimely adjustment of the effect of security factors can cause a change in their level, as a result of which they acquire a destabilizing capacity in the conditions of uncertainty, which is perceived as a threat to economic security. Therefore, it is recommended to investigate the level of social and economic development of regions and use the composite fuel poverty index to assess the «bottlenecks» of regional energy security in order to prevent the transformation of threats into insecurity and crisis situations. The assessment of regional energy security is a topical and constantly much-in-demand research under the influence of a system of exogenous and endogenous factors. Such a need has long been discussed among scientists, yet there are still various points of view regarding the methodology for assessing the level of energy security as a constituent part of the country's economic security. This research will allow us not only to determine the system of both exogenous and endogenous factors affecting regional energy security and having a potential for their transforming into a threat to economic security, but also to conduct a comprehensive monitoring of the development level by region.

2. Brief Literature Review

In spite of significant progress in the study of various forms of assessing the social and economic situation in the current conditions of economic transformation in Ukraine, the existing methodology for assessing regional energy security in the course of economic transformation is still underdeveloped. The relevance of the study on the issues of low purchasing power of households and the search for ways to ensure uninterrupted energy supply to households is emphasised by many scientists, since the issue of fuel poverty is a major obstacle to structural changes in social and economic development, where human welfare should be the major objective for functioning of the economic system.

Thus, the survey study conducted by A. Ambrose and R. Marchand (2017) is devoted to a critical overview of recent research on fuel poverty, mainly in the EU countries. The authors emphasise the diversity of methodological approaches to the study of this phenomenon, reflecting both the dynamics of fuel poverty and its geography in the regional context of the country of interest. In fact, however, the aforementioned researchers considered only highly developed countries and made no reference at all to the study of fuel poverty in Asian or Eastern European countries. On the contrary, V. Ezratty (2017) was engaged in adapting the English approach to the assessment of healthcare expenditures associated with energy-inefficient apartment buildings. He adapted it to the French realia subject to somewhat different climatic features than those in England and Wales. It is clear that inadequate heating results in an increased risk of cold-related diseases in the cold season. We did not consider this critical result of fuel poverty, although it is certainly pertinent to Ukrainian households. C. N. B. Grey et al. (2017) studied the influence of living conditions in the three selected low-income Welsh communities on the level of fuel poverty before and after receiving a subsidy to improve the energy efficiency of buildings. Understandably, such an approach requires a separate state policy to handle this phenomenon. However, this study was not comprehensive in the regional context. T. Harriet and C. Snell (2013) conducted a comparative analysis of the fuel poverty levels in the EU countries with a particular focus on the Southern and Eastern European countries, namely the countries of the former socialist camp. After all, in these countries, low household income and poor housing conditions cause a high level of fuel poverty. For their analysis, the authors resorted to surveys. T. Harriet, S. Bouzarovski and C. Snell (2017) critically assess available static indicators used to assess fuel poverty

in the European Union. This approach is due to the lack of consensus in the strict definition of the concept of fuel poverty and its measurement. R. Mold and K. J. Baker (2017) conducted a study of Scottish rural and urban households and found that rural low-income households spend more on energy resources than urban ones with comparable income level and more than rural ones with higher income level. On the contrary, K. O'Sullivan and P. Howden-Chapman (2017) analysed the consequences of fuel poverty and possible ways to overcome it. G. Walker and R. Day (2012) consider legal and social aspects of fuel poverty, as well as ways to involve relevant marginalised (energy poor) social groups in decision-making. To the problems of techno-organisational change in the European Union and achieving EU 2030 and 2050 targets in the spheres of green economy and energy policy is devoted a research of M. Mazzanti and U. Rizzo (2017).

Summarising this brief review, it is worth mentioning that our study concerns Ukraine, where it is proposed to assess the level of fuel poverty at the regional macro level. This is because most of the aforementioned researchers obtained calculation data on the basis of surveys involving certain social groups in several basic regions. The authors did not have such an opportunity. Therefore, we resorted to studying the macro-level of fuel poverty, i.e. identifying the regions that suffer most from inconsistencies of household income with energy costs at this level.

From this perspective, our studies are closest to those conducted by T. Harriet and C. Snell (2013), D. Charlier and B. Legendre (2016), and J. Hills (2011), yet they are different in terms of their regional context and the amount of statistical data used with reference to the relevant Ukrainian resources.

3. The purpose of the research is to develop a methodology for determining the composite fuel poverty index by region, revealing the principal factors of its formation, as well as to determine the level of energy security in terms of constructing a socially-oriented market economy in Ukraine.

4. Results

In the current social and economic context, the determination of the essence and role of security requires consideration of its antipode - insecurity - as a phenomenon that is actually or potentially capable of affecting the qualitative and quantitative variables of development and acting as a form of aggravation of social contradictions. In the course of studying social and economic security, insecurity reveals itself as an objectively existing potential for adversely affecting the social organism with the resulting significant losses, which not only degrade its condition, but also bring about undesirable parameters to the object (nature, rates, forms, etc.). In this case, Various conditions and factors that reveal hostile intentions, noxious properties, and destructive nature and have a natural, social or anthropogenic origin either on their own or in different combinations under certain circumstances are the sources of insecurity [9]. Social and economic security is the fundamental category of the global community and the basis of the future economy. At the regional level, the definition of social and economic security is preceded by modelling and diagnosing its social and economic development to determine the quantitative values of economic security indicators. The modelling of regional growth is an indispensable element in determining the effectiveness of the social and economic state for comparing regions and working out strategies for their development. The need to compare social and economic development of regions is based on the current trends of the regionalisation of the economy. Our approach to modelling the assessment of the regional energy security level through the prism of its fuel poverty index provides for the formation of models for calculating the costs and consumption of fuel and energy resources by regions' households. The consistent theoretical substantiation of the proposed approach and the availability of methods of its practical application ensure the identification of issues of public social and economic policies to make adequate decisions in terms of Ukraine's energy market deregulation and transformation of the economic system as a whole. We propose an analytical macroeconomic model of regional energy inefficiency as a basic model for forecasting and diagnosing the social and economic development of Ukrainian regions. The fact that the model is based on the principles of the consistent approach allowed us to build a macroeconomic model for estimating fuel poverty by region by using the monetary poverty and energy inefficiency indicators.

The level of social monetary poverty P_i was measured as a ratio of the average household income in Ukraine to the same household in the region to calculate the monetary poverty indicator. After that, we measured the maximum and minimum values P for the corresponding year. In view of the foregoing, the monetary poverty indicator for the period (year) under study shall be understood to mean the ratio of the difference of the parameter P for the region and the minimum parameter P for all regions to the difference between the largest and the smallest values of the parameter P.

A similar approach was used to determine the energy efficiency indicator. Its criterion was the consumption of all types of energy resources per 1 sq.m of the region's household area in terms of tons of fuel oil equivalent. The energy efficiency indicator was calculated according to the same approach as the monetary poverty indicator described above.

Unfortunately, the fuel poverty model did not include the indicator of calculating the potential heating conditions, since we do not have the relevant statistical data to that effect. On the other hand, they can be obtained only by a field survey of a large sample of households throughout Ukraine, which requires both significant financial resources and the development of a set of technical merits for surveying households, since such information is individual and varies greatly with the type of household. Therefore, the composite fuel poverty index proposed by us considers only two components - monetary poverty and energy inefficiency, and is calculated as their geometric mean, i.e. the square root of their product.

Given the contribution of each component, the integrated index of social and economic development that reflects the fuel poverty of regions is expressed as follows:

$$FPI_i = \sqrt{I_{pi} \cdot I_{ci}}\,, \tag{1}$$

where FPI_i is the fuel poverty index in the i-th region for the corresponding year;

I_{pi} is the monetary poverty index in the i-th region for the corresponding year, where

$I_{pi} = (P_i - \min(P_i)) \,/\, (\max(P_i) - \min\,(P_i))$.

We propose to calculate the region's monetary poverty indicator as follows:

$$P_i = HI \,/\, HI_i\,, \tag{2}$$

where

HI is average household income in Ukraine for the year;

HI_i is household income in the i-th region for the same year.

Therefore, $\min\,(P_i)$ is the lowest money poverty of all regions for the corresponding year, and $(\max\,(P_i)$ is the highest monetary poverty of all regions for the corresponding year.

We propose to calculate the energy inefficiency indicator in the i-th region for the corresponding year (I_{ci}) by the formula:

$$I_{ci} = (C_i - \min(C_i)) \,/\, (\max(C_i) - \min\,(C_i))\,, \tag{3}$$

where C_i is energy inefficiency determined as a ratio of consumption by Ukraine's average household of the relevant energy resources for the year in terms of oil equivalent to the residential area of the household S_i in the i-th region for the same year, i.e.:

$C_i = (W_i * KW + G_i * KG + E_i * KE + T_i * KT + C_i * KC + D_i * KD + B_i * KB) / S_i$,

where W_i, G_i, E_i, T_i, C_i, D_i, B_i, are volumes of consumption of heat energy, gas, electricity, peat, coal, firewood, liquefied butane and propane, respectively, per household in the i-th region per year, and KW, KG, KE, KT, KC, KD, KB are

coefficients of conversion of the corresponding type of energy resources into the oil equivalent; in addition, $\min(C_i)$ is the lowest energy inefficiency of all regions for the corresponding year, and $\max(C_i)$ is the highest energy inefficiency of all regions for the corresponding year.

It should be noted that Sevastopol and the Autonomous Republic of Crimea were taken into account for 2012 and 2013 only. The statistical data on Luhansk and Donetsk regions may be incomplete, given the anti-terrorist operation on these territories.

It is the model construction, where social monetary poverty and energy inefficiency are exogenous and endogenous parameters, which provides the breadth of functionality, i.e. the emergent model properties in assessing the state of and forecasting social and economic development of the regions. Each trend includes a list of issues to be solved, namely a mathematical calculation of the monetary poverty index in the country's economy and the level of energy efficiency of households, the development of possible options for improving energy security, the substantiation of the points of influence of the supply-side policies, the synthesis of control actions to ensure targets of economic growth and energy market pricing policy.

The calculation of the composite fuel poverty index enables us to estimate regions with low incomes and a high level of consumption of fuel and energy resources per 1 sq.m of the household area, and it can be clearly seen from Figure 2 that the monetary poverty of Ukrainian regions was greater than fuel poverty during the period of 2012-2016, although all regions are critically close to the fuel poverty threshold. The findings show that calculations of the region's composite fuel poverty index can be an integral part in the development of a strategy for social and economic development and highlight the problematic aspects of the region's energy security.

The dynamics of the composite fuel poverty index of Ukrainian regions shown in Figure 1 indicates the possibility of using macroeconomic tools to examine the interaction of critical variables (household income, household consumption of fuel and energy resources, average household area, number of households, population, and fuel and energy resources price behaviour) considering regional specific features, and supports its adequacy in application. The value of the aggregate index given in Table 2 confirms the sustainability of the index when compared with the aggregate index data shown in Table 1. Figure 1 shows that during 2012-2016, the fuel poverty index was established in the range of 0.5 to 0.65. However, the index fluctuations are affected to a great extent by increases in prices on fuel and energy resources, with a high value of the index being indicative of a low level of household income and high expenditures on fuel and energy resources for Ukrainian households. In addition, a high fuel poverty index was observed in 2015, when gas prices for the population skyrocketed by about 7 times, whereas the net income of households grew by only 10%.

In our opinion, this approach provides greater facilities for modelling, forecasting and diagnosing economic systems than statistical ones and allows assessing the energy security of regions and, on this basis, identify vulnerable social groups that require support to overcome fuel poverty.

The calculations in Table 1, Table 2 and Figure 1 show that the country's social and economic regional development demonstrates gradual deterioration. Each of the methods of

Tab. 1: **Calculation of regions' composite fuel poverty index by using three approaches**

Indicators / Years	2012	2013	2014	2015	2016
Approach: After Fuel Cost Poverty 60 Percent					
Population, people	28,976,790	26,099,124	35,744,074	30993124	32998751
Households, thousand	10,775	9,773.7	13,045.4	11,795.5	11,504.2
Total household income, UAH million	625,188.49	591,376.94	856,372.12	911,837.66	1,006,746.58
Income of one household, UAH	58,022.13	60,506.96	65,645.52	77,303.86	87,511.22
Monetary poverty level	1.16	1.18	1.21	1.14	1.16
Monetary poverty index	0.74	0.75	0.68	0.70	0.75
Area of households, sq.m	697,630,135	637,001,787	886,927,002	785,330,200	842,836,766
Consumption of FER, thousand TOE	19,256.62	18,780.52	24,420.19	19,932.88	22,342.45
Indicator of fuel consumption per unit area, TOE /sq.m	0.028	0.029	0.028	0.025	0.027
Energy inefficiency index	0.34	0.41	0.38	0.42	0.36
Aggregate index	**0.51**	**0.55**	**0.51**	**0.54**	**0.52**
Approach: 10% Ratio Approach Energy Income Ratio					
Population, people	0	1,066,826	0	37,463,658	36,216,617
Households, thousand	0	448.7	0	13,087.3	12,638.7
Total household income, UAH million	0	25,176.78	0	1,032,502.73	1,132,781.27
Income of one household, UAH	-	56,110.48	-	78,893.41	89,627.99
Household energy costs, UAH	0	3,956,127.84	0	152,950,966.3	179,186,637.4
Monetary poverty level	-	1.28	-	1.12	1.13
Monetary poverty index	-	0.85	-	0.68	0.72
Area of households, sq.m	0	29,985,886	0	938,379,880	916,207,149
Consumption of FER, thousand TOE	0	673,581.87	0	23,617.34	24,712.98
Indicator of fuel consumption per unit area, TOE /sq.m	-	0.02	-	0.03	0.03
Energy inefficiency index	-	0.25	-	0.42	0.37
Aggregate index	**-**	**0.46**	**-**	**0.53**	**0.52**
Approach: LIHC					
Population, people	5,000,970	7,303,498	9,503,099	12,879,971	17,110,840
Households, thousand	1,942.3	2,910.6	3,673.5	4,906.3	6,017.1
Total household income, UAH million	122,465.31	181,179.55	279,217.17	405,508.57	556,230.26
Income of one household, UAH	63,051.69	62,248.18	76,008.49	82,650.58	92,424.97
Monetary poverty level	1.07	1.15	1.046	1.066	1.097
Monetary poverty index	0.64	0.72	0.53	0.63	0.68
Area of households, sq.m	120,212,723	183,831,849	244,072,774	336,418,230	438,507,463
FER consumption, thousand TOE	3,983.05	6,379.23	8,843.86	10,622.63	14,638.08
Indicator of fuel consumption per unit area, TOE /sq.m	0.03	0.04	0.04	0.03	0.03
Energy inefficiency index	0.45	0.51	0.62	0.63	0.51
Aggregate index	**0.54**	**0.61**	**0.57**	**0.63**	**0.59**
Aggregate index	**0.50**	**0.52**	**0.51**	**0.51**	**0.48**

Note: FER - fuel and energy resources; TOE - Tonne of oil equivalent
Source: Compiled by the authors based on [14-16]

Tab. 2: **Calculation of composite fuel poverty index without 2 best and 2 worst regions**

Indicators / Years	2012	2013	2014	2015	2016
Population, people	36,760,241	35,379,816	34,256,905	31,903,453	33,531,097
Households, thousand	13,568.2	13,015.7	12,017.6	10,786.6	11,941.3
Total household income, UAH million	841,422.83	859,374.41	809,137.27	846,148.39	1,091,757.68
Income of one household, UAH	61,940.63	66,025.98	67,329.36	78,444.41	91,427.04
Monetary poverty level	1.09	1.08	1.18	1.12	1.11
Monetary poverty index	0.66	0.65	0.65	0.68	0.69
Area of households, sq.m	889,865,735	858,590,334	840,817,081	799,763,226	845,092,644
Consumption of FER, thousand TOE	27,831.46	27,032.42	22,482.17	18,742.69	20,672.14
Indicator of fuel consumption per unit area, TOE /sq.m	0.03	0.03	0.03	0.02	0.02
Energy inefficiency index	0.41	0.44	0.36	0.36	0.32
Aggregate index without outermost regions	**0.52**	**0.54**	**0.49**	**0.49**	**0.47**

Source: Compiled by the authors based on [14-16]

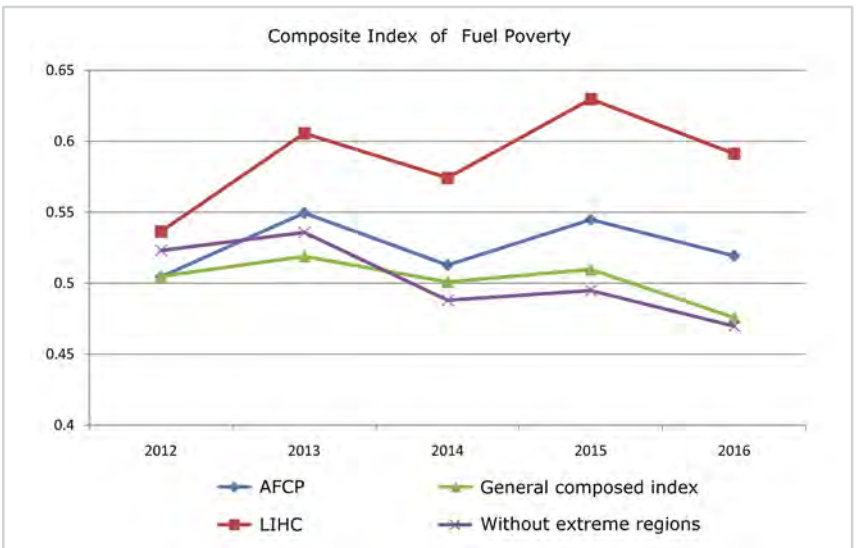

Fig. 1: **Composite fuel poverty index over time**
Source: Compiled by the authors

calculating the level of fuel poverty, shown in Table 2, demonstrates the high aggregate index and is close to unity. It is only the «10% Ratio Approach Energy Income Ratio» method where the index is 0 for 2012 and 2014, which means that there were no regions then, where the average household spent more than 10% of net income for fuel and energy.

This value implicitly indicates a non-market price of energy resources for the population and a high level of subsidization of prices by the state. In Ukraine, however, personal income cannot be called high, and this means the absence in the corresponding years of a robust market mechanism of pricing for fuel and energy resources directly consumed by the population. The calculation of fuel poverty by using the three approaches given in Table 2 and Table 3 indicates the fact of this phenomenon, with the composite index being high. The existence of fuel poverty in Ukraine is evidenced by graphs a, b, c, d, e shown in Figure 2, where

Tab. 3: **Calculation Data on Constituents of the Composite Fuel Poverty Index**

Ukrainian Regions	Monetary Poverty Level					Monetary Poverty Index					Energy Inefficiency Index					Aggregate Fuel Poverty Index				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Ukraine	1	1	1	1	1	0.56	0.55	0.49	0.57	0.59	0.45	0.48	0.52	0.47	0.39	0.51	0.52	0.50	0.51	0.48
The Autonomous Republic of Crimea	1.22	1.17	-	-	-	0.79	0.74	-	-	-	0.21	0.22	-	-	-	0.41	0.40	-	-	-
Vinnytsia	1.23	1.23	1.35	1.22	1.21	0.81	0.81	0.81	0.78	0.79	0.23	0.20	0.12	0.08	0.12	0.44	0.41	0.30	0.25	0.32
Volyn	1.16	1.16	1.27	1.17	1.14	0.73	0.73	0.74	0.74	0.73	0.26	0.25	0.18	0.13	0.18	0.44	0.43	0.37	0.31	0.36
Dnipropetrovsk	0.93	0.94	0.99	0.96	0.99	0.49	0.49	0.48	0.52	0.58	1	1	1	1	0.71	0.71	0.71	0.69	0.72	0.64
Donetsk	0.89	0.89	0.92	0.94	1.14	0.44	0.44	0.41	0.50	0.73	0.82	0.86	0.61	0.38	0.19	0.61	0.62	0.50	0.44	0.38
Zhytomyr	1.23	1.29	1.41	1.29	1.27	0.82	0.86	0.86	0.84	0.86	0.27	0.29	0	0.21	0.22	0.47	0.51	0	0.42	0.43
Transcarpathian	1.12	1.13	1.29	1.15	1.12	0.69	0.69	0.76	0.71	0.71	0.32	0.31	0.18	0.16	0.19	0.47	0.47	0.37	0.34	0.37
Zaporizhzhia	0.96	0.98	1.03	1.02	0.99	0.52	0.53	0.51	0.58	0.58	0.63	0.59	0.65	0.72	0.45	0.58	0.56	0.57	0.65	0.51
Ivano-Frankivsk	1.11	1.11	1.28	1.12	1.09	0.67	0.68	0.74	0.68	0.67	0.58	0.64	0.57	0.57	0.56	0.62	0.65	0.65	0.62	0.62
Kyiv	0.95	0.97	1.04	0.99	0.98	0.50	0.53	0.52	0.56	0.57	0.42	0.64	0.43	0.35	0.29	0.46	0.58	0.47	0.45	0.41
Kirovohrad	1.41	1.42	1.56	1.44	1.41	1	1	1	1	1	0.32	0.32	0.34	0.36	0.27	0.56	0.57	0.58	0.59	0.52
Luhansk	1.14	1.13	1.13	0.95	1.32	0.71	0.71	0.60	0.56	0.91	0.59	0.69	0.18	0.38	0	0.65	0.69	0.33	0.45	0
Lviv	0.99	0.99	1.09	0.99	0.97	0.55	0.56	0.56	0.56	0.55	0.49	0.52	0.41	0.52	0.34	0.52	0.54	0.48	0.54	0.44
Mykolaiv	1.13	1.15	1.30	1.19	1.17	0.70	0.72	0.76	0.76	0.76	0.45	0.52	0.45	0.46	0.39	0.56	0.61	0.58	0.59	0.55
Odesa	1.07	0.98	1.15	1.04	0.99	0.63	0.54	0.62	0.61	0.58	0.17	0.18	0.13	0.08	0.14	0.33	0.31	0.29	0.23	0.29
Poltava	1.16	1.16	1.26	1.18	1.16	0.73	0.73	0.72	0.74	0.75	0.53	0.56	0.59	0.60	0.49	0.62	0.64	0.65	0.67	0.61
Rivne	1.11	1.99	1.18	1.10	1.09	0.68	0.66	0.65	0.66	0.68	0.47	0.46	0.44	0.44	0.36	0.56	0.55	0.54	0.54	0.49
Sumy	1.18	1.19	1.31	1.19	1.19	0.74	0.76	0.7	0.76	0.77	0.37	0.38	0.33	0.29	0.32	0.53	0.53	0.51	0.47	0.49
Ternopil	1.22	1.26	1.45	1.27	1.28	0.79	0.84	0.90	0.83	0.86	0.34	0.34	0.29	0.19	0.25	0.53	0.54	0.51	0.41	0.47
Kharkiv	1.02	1.03	1.14	1.15	1.14	0.58	0.59	0.61	0.71	0.72	0.33	0.34	0.32	0.24	1	0.44	0.45	0.45	0.42	0.85
Kherson	1.27	1.24	1.45	1.25	1.23	0.85	0.82	0.90	0.81	0.82	0.18	0.17	0.12	0.08	0.10	0.39	0.37	0.34	0.25	0.29
Khmelnytskyi	1.17	1.17	1.31	1.15	1.15	0.74	0.74	0.76	0.72	0.74	0.38	0.40	0.38	0.50	0.33	0.53	0.55	0.55	0.60	0.49
Cherkasy	1.35	1.38	1.55	1.42	1.39	0.94	0.96	0.96	0.97	0.98	0.36	0.76	0.54	0.69	0.53	0.58	0.85	0.73	0.82	0.72
Chernivtsi	1.26	1.24	1.45	1.29	1.27	0.84	0.81	0.89	0.84	0.86	0.31	0.29	0.24	0.19	0.19	0.51	0.48	0.47	0.41	0.41
Chernihiv	1.25	1.28	1.46	1.36	1.36	0.83	0.85	0.90	0.91	0.95	0.26	0.25	0.19	0.14	0.22	0.46	0.45	0.43	0.35	0.46
Kyiv city	0.48	0.47	0.47	0.44	0.42	0	0	0	0	0	0.24	0.27	0.13	0	0.12	0	0	0	0	0
Sevastopol	1.02	0.93	-	-	-	0.58	0.49	-	-	-	0	0	-	-	-	0	0	-	-	-

Source: Compiled by the authors based on [14-16]

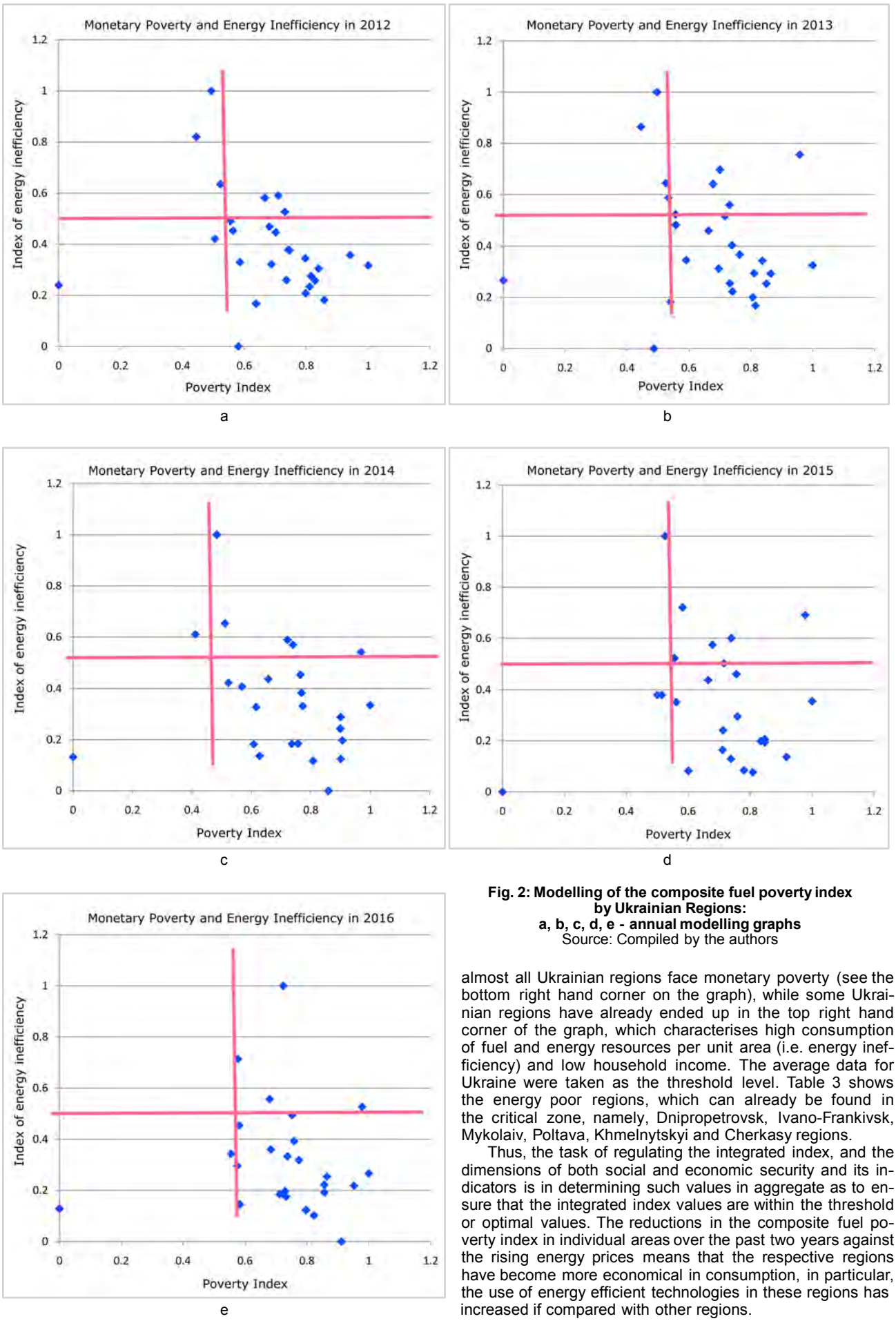

Fig. 2: Modelling of the composite fuel poverty index by Ukrainian Regions: a, b, c, d, e - annual modelling graphs
Source: Compiled by the authors

almost all Ukrainian regions face monetary poverty (see the bottom right hand corner on the graph), while some Ukrainian regions have already ended up in the top right hand corner of the graph, which characterises high consumption of fuel and energy resources per unit area (i.e. energy inefficiency) and low household income. The average data for Ukraine were taken as the threshold level. Table 3 shows the energy poor regions, which can already be found in the critical zone, namely, Dnipropetrovsk, Ivano-Frankivsk, Mykolaiv, Poltava, Khmelnytskyi and Cherkasy regions.

Thus, the task of regulating the integrated index, and the dimensions of both social and economic security and its indicators is in determining such values in aggregate as to ensure that the integrated index values are within the threshold or optimal values. The reductions in the composite fuel poverty index in individual areas over the past two years against the rising energy prices means that the respective regions have become more economical in consumption, in particular, the use of energy efficient technologies in these regions has increased if compared with other regions.

5. Conclusions

1. The need to develop a methodology for studying the fuel poverty phenomenon arose in the conditions of a decrease in the solvency of the population, the growth of debts for housing and public utility services, and the escalation of social tension. It is found that energy poor households are considered to be those whose energy costs exceed a certain percentage of their disposable income. Our methodology of estimating the region's composite fuel poverty index is instrumental in determining the ranking of energy poor regions for the purpose of developing and implementing measures to overcome energy security threats in the aspect of building a socially-oriented market economy in Ukraine.
2. The calculation data show that the share of fuel and energy costs as part of household costs exceeded 10% of households' income threshold for 2012-2016, resulting in low living standards of the population and hardship in meeting basic needs. Further increase in fuel and energy prices will bring about an increase in social tension.
3. The methodology for determining social and economic insecurity should be implemented at the institutional level, since the existing methodology does not allow assessing the level of fuel poverty of the population at all. Therefore, in order to overcome the existing threats to energy security, the Cabinet of Ministers of Ukraine, the Ministry of Social Policy of Ukraine, the Ministry of Finance of Ukraine, the State Agency on Energy Efficiency and Energy Saving of Ukraine, the National Commission for State Regulation of Energy and Public Utilities should develop and implement a methodology for estimating fuel poverty of the population using best practices of European countries.
4. Our methodology and algorithm for calculating the region's composite fuel poverty index enable to measure the aggregate indicators for assessing the energy efficiency of households, with the approach to establishing threshold values for determining «fuel poverty», providing means to improving the mechanism of institutional provision of social and economic security.
5. An in-depth analysis of the constituents of the composite fuel poverty index allows identifying the «bottlenecks» of energy security of Ukrainian regions, which should be considered when developing relevant strategies.
6. Regional policies should focus on meeting social and economic criteria, including an increase in employment and levels of personal income; provision of differentiation of energy resources; introduction of energy saving technologies; refinement of public subsidy programs in terms of supporting socially vulnerable groups.

The hierarchy of these criteria defines the approach to further modelling of Ukraine's energy security and forecasting of indicators for assessing social and economic security of regions in subsequent studies.

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