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Economic Growth and Energy Development: Determining the Interaction

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***Abstract*—The article reviews current trends in global energy sector for the last ten years, illustrating energy contribution to economic and social development and highlighting gains and losses from energy commercialization for producers and users. The interaction between economic growth and energy market movements as well as advanced achievements in energy sector is examined on a number of countries. For testing it empirically, a linear regression model was simulated to determine the correlation between the gross output and energy sector indicators. By applying World Bank data two models for Germany and the Russian Federation were developed. The possibility of thermodynamics theory application to advance technologies of fuel and energy resources utilization is considered. Consequently, the system of corresponding knowledge as to the rational and efficient energy use for assuring the security of energy supply is to be generated. Energy security is viewed as a keystone of global sustainability.**

Keywords— energy development; economic growth; fuel and energy resources; renewable energy; energy intensity; knowledge; research and development expenditure

INTRODUCTION

The humanity is currently on the verge of a new energy era. Energy is viewed as an organic part of human being and a resource of high market value and utility. As to the estimations, global energy use has increased by 44 % since 1970 [1]. Global demand for energy is expected to grow up on 60% by 2030 [2]. Global oil consumption has also expanded by 20% since 1994. As to the global oil demand, it will go up on 1.6% per year [2]. These facts confirm stable tendency to energy dominance among other natural resources regarding their social and economic utility. Consequently, the problem how to transform ample energy available on earth into socially-oriented capital to meet rapidly growing human needs with maximum utility and minimum pressure on environment is on the agenda. For its solution, not only new rational production patterns and technologies are needed, but a unified global energy strategy is set to be developed [3-7]. In the frame of this article, we also attempt to find a solution how to rationalize energy use. We do it by examining the interaction between economic growth and energy use and exploring the possibility of thermodynamics theory application to energy system modernization.

LITERATURE REVIEW

A considerable body of work supports the opinion that namely energy drives modern growth. The higher the rate of growth is, the more energy-consuming the economy gets. Although energy is widely used, countries always face difficulties in applied technologies to get and utilize it in a proper manner. Understanding visible limits in non-renewable energy sources and constantly growing demand for energy, they are urgently searching for an extraordinary policy to secure energy supply and restore sustainability in the long run. This dilemma becomes a burning issue not only for scientists and economists, but also for policymaker, whose ideas we put into context to develop recommendations for secure and rational energy use.

Among the first, empirically confirmed correlation between economic growth and energy use, there were Bruno Fritsch, S. Schmidheiny, and W. Seifritz (1994) [8]. Having observed energy flows between the Earth and Space in relation to basic economic needs they raised a concern that "…we do not depend entirely on fossil energy sources. They are just handy, cheap, and as fuel, rich in energy per unit volume. That is why we use them. If they become more expensive because of rising cost of exploration, or decreasing concentrations per unit volume … other substitutes enter the scene" (p. 58). Scientists proposed to divide the transition of energy sources from depletion to their total substitution into three stages. At stage 1, the society continues to use non-renewable resources at present patterns. It will last for the next 30 to 50 years. During stage 2 people would consume less non-renewable resources due to their tangible limits, and switch to alternative sources of energy. It might take several hundred years. In stage 3, they would go into the Age of Sustainability when conditions of life are based "almost exclusively on materials that are virtually unlimited" (p. 58). In such a manner, scientists confirm that sustainability is achievable due to substitutability of energy sources and advanced knowledge.

Inter-linkages between energy and economic growth were thoroughly explored by Julian Simon (1996) [9]. The scientist is convinced that by stimulating scientific research in energy related sectors and implementing energy efficient innovative technologies the humanity can steadily switch to optimal energy mix sufficient to accelerate economic growth in the long run. The limits in nonrenewable energy reserves people might reduce incorporating different kinds of knowledge in production cycle. In such a way, society gets a solution for the most arguable dilemma of expanding limits of economic growth.

Following the review, it is worth mentioning the OECD approach to assessing the energy contribution to sustainable development (2008) [10]. OECD maintains the perception that "energy efficiency improvement, renewable energy and changes in consumption, behavior and management patterns are necessary to restore long-term sustainability" (p.111). Compared to above-mentioned approaches this approach covers more dimensions, takes into account consumption patterns, assumes new priorities in energy consumption policy and searches for an optimal mix of energy resources to meet constantly growing demand for energy.

The next paper is a survey of energy cultures conducted by Barton, Blackwell, Carrington, Ford, Lawson, Stephenson, Thorsnes and Williams [11], scientists from the Centre for Sustainability in University of Otago. The authors reveal energy behavior of households in New Zealand. It is a complex research divided into multiple sub-projects aimed to examine values and behavior, energy culture clusters, consumer choice, energy performance standards, changes in energy behavior, invention, hot water heating choices and legal framework. The research proposes an alternative energy policy framework based on norms, material culture and advanced energy practices.

Another study of energy policy framework was conducted by Mei-Shiu Chiu (2013) [12]. The author investigated Taiwanese energy policy in terms of traditional cultural values.

Cantner, Graf, Herrmann and Kalthaus (2016) [13], a research team from Friedrich Schiller University Jena, discussed in their paper energy policy incentives used to stimulate inventive activities as to renewable power generation in Germany. Have reviewed incentives range and its influence on technological change and wind power generation in Germany since 1980, the researchers arrived at the conclusion that inventor networks appeared to be the most functional mechanism for fostering technological change in renewable power generation sector. Government support is essential and is supposed to be systematic. The network structure is flexible and depends on demand pull for advanced renewable energy technologies.

ANALYSIS AND DISCUSSION

In this section, interdependence between economic growth, research and energy sector development is tested empirically. To determine links, a linear regression model is developed. In the model (1), GDP per capita is regarded as an output function with the following independent variables:

$$a_0 + a_1 * x_1 + ... + a_6 * x_6 = \gamma \qquad (1)$$

γ – output function;

x_1 – research and development expenditure (% of GDP);

x_2 – renewable electricity output (% of total electricity output);

x_3 – energy intensity level of primary energy (MJ/$2011 PPP GDP);

x_4 – energy use (kg of oil equivalent per capita);

x_5 – patent applications, residents;

x_6 – renewable energy consumption (% of total final energy consumption);

a_i – indicator of regression

Two models for Germany and the Russian Federation have been simulated. Initial data for simulations were taken from the World Bank database and submitted in Table I and Table II [14-20].

TABLE I. INITIAL DATA FOR SIMULATION MODEL, CASE OF RUSSIAN FEDERATION

Year	Output function, γ	Arguments					
		x_1	x_2	x_3	x_4	x_5	x_6
2000	1771,6	1,05	18,73	12,59	4224	23377	3,50
2001	2100,4	1,18	19,57	12,11	4288	24777	3,62
2002	2375,1	1,25	18,26	11,51	4288	23712	3,46
2003	2975,1	1,29	17,08	11,11	4461	24969	3,28
2004	4102,4	1,15	18,96	10,39	4494	22985	3,55
2005	5323,5	1,07	18,20	9,84	4541	23644	3,62
2006	6920,2	1,07	17,49	9,36	4688	27884	3,48
2007	9101,3	1,12	17,52	8,65	4710	27505	3,67
2008	11635,3	1,04	15,91	8,41	4823	27712	3,31
2009	8562,8	1,25	17,64	8,58	4531	25598	3,60
2010	10675,0	1,13	16,12	8,73	4819	28722	3,34
2011	14351,2	1,02	15,80	8,78	5049	26495	3,23
2012	15434,6	1,05	15,56	8,69	5167	28701	3,35
2013	16007,1	1,06	17,18	8,46	5079	28765	3,75
2014	14125,9	1,09	16,57	8,35	4943	24072	3,42
2015	9329,3	1,13	15,72[a]	8,41	5210[a]	29269	3,30

[a]. *data obtained by trend line extrapolation*

TABLE II. INITIAL DATA FOR SIMULATION MODEL, CASE OF GERMANY

Year	Output function, γ	Arguments					
		x_1	x_2	x_3	x_4	x_5	x_6
2000	23718,7	2,40	6,20	4,64	4094	51736	3,70
2001	23687,3	2,39	6,51	4,69	4210	49989	3,90
2002	25205,2	2,42	7,64	4,59	4108	47598	4,41
2003	30360,0	2,46	7,55	4,60	4085	47818	5,06
2004	34165,9	2,42	9,27	4,58	4114	48448	5,83
2005	34696,6	2,43	10,15	4,51	4087	48367	6,77
2006	36447,9	2,46	11,32	4,47	4205	48012	7,75
2007	41814,8	2,45	13,94	4,10	3986	47853	9,41
2008	45699,2	2,60	14,7	4,10	4037	49240	8,59
2009	41732,7	2,73	16,08	4,07	3791	47859	9,63
2010	41785,6	2,71	16,73	4,12	3997	47047	10,29
2011	46810,3	2,80	20,38	3,77	3870	46986	11,39
2012	44065,2	2,87	23,00	3,77	3877	46620	12,02
2013	46530,9	2,82	24,07	3,83	3940	47353	12,09
2014	48042,6	2,89	26,13	3,64	3779	48154	13,38
2015	41323,9	2,88	30,30 [b]	3,60	3818	47384	14,21

[b.] *data obtained by trend line extrapolation*

The first step is a correlation analysis. It allows to determine links between an output function and its variables, as well as links between variables themselves. The correlation is considered strong if its coefficient is higher than 0.60. If the coefficient exceeds 0.80, it is regarded as very strong. To provide true and fair findings in the frame of current research, the coefficient 0.70 is accepted to be a threshold requirement for selecting arguments that have impact on an outcome. The results of correlation analysis are presented in Table III and Table IV.

Analyzing data in Table III, we see that research and development expenditure, patent applications and renewable energy consumption have low or moderate impact on GDP in the Russian Federation. Other arguments have very strong impact. In Germany, patent applications have low negative impact on growth (Table IV). That might be explained by insufficient number of patents existing in energy sector.

TABLE III. MATRIX OF PAIR CORRELATION (R), CASE OF RUSSIAN FEDERATION

	γ	x_1	x_2	x_3	x_4	x_5	x_6
γ	1						
x_1	-0,56	1					
x_2	-0,81	0,35	1				
x_3	-0,86	0,37	0,76	1			
x_4	0,90	-0,52	-0,86	-0,85	1		
x_5	0,66	-0,32	-0,72	-0,68	0,76	1	
x_6	-0,18	0,05	0,67	0,14	-0,34	-0,21	1

TABLE IV. MATRIX OF PAIR CORRELATION (R), CASE OF GERMANY

	γ	x_1	x_2	x_3	x_4	x_5	x_6
γ	1						
x_1	0,81	1					
x_2	0,90	0,95	1				
x_3	-0,88	-0,95	-0,97	1			
x_4	-0,74	-0,89	-0,85	0,89	1		
x_5	-0,60	-0,57	-0,57	0,57	0,48	1	
x_6	0,90	0,93	0,98	-0,98	-0,84	-0,63	1

The next step is a regression analysis. It is a mathematical approach for studying linkages between different variables. Processing cases of Germany and the Russian Federation, two models of multiple regressions were developed by means of MS EXCEL option "Regression".

Summarizing the results of regression analysis (see Table V) we may agree that the model constructed for the Russian Federation could be described as reliable one. Its R-squared value equals to 0,908, that indicates a high level of model accuracy and adequacy (the regression is better, than closer to 1). The reliability of obtained results is justified by means of "Significance F". Normally, it should be less than 0,05. In the model, "Significance F" equals to 0,0003. It means the results are reliable. Regression equation is written as:

$$7916,05 - 3239,88x_2 - 259,87x_3 + 6,26x_4 = \gamma \quad (2)$$

In case of Germany, a developed regression model is also reliable. R-squared value equals to 0,919 and confirms high model accuracy and adequacy. The reliability of the model is also high, as the "Significance F" equals to 0,0001. Regression equation is written as:

$$4809,5 + 11217x_1 - 2053x_2 - 17488x_3 + 13x_4 + 4605,6x_6 = \gamma \quad (3)$$

Both regression models for Germany and for the Russian Federation give ground for justifying high interdependence between economic growth and energy sector development. In Germany, it seems to be stronger and more visible, in Russia – less visible, but still significant. Warning sign is loosely correlation of research and development expenditure and patent applications to output function.

TABLE V. MATRIX OF PAIR CORRELATION (R), CASE OF GERMANY

The regression statistics	Country	
	Russian Federation	*Germany*
Multiple R	0,952888389	0,95907
R-square	0,907996283	0,919815
Adjusted R-square	0,846660471	0,866359
Standard error	1950,200293	3072,9
Observations	16	16

FINDING SOLUTIONS

In our opinion, thermodynamics theory has the advantage where it is required to sustain economic growth in the long run. The theory supposes, that materia could be transformed into a new shape or a new state by means of special knowledge. If we describe materia, energy and knowledge as structural elements of economic system, we may expect that economic growth will depend on changes in elements structure and content as well as the way they interact. Therefore, growth may be considered as a dual process. On the one hand, materia transformations decrease energy potential and impose certain limitations. On the other hand, knowledge accumulation and deployment allow to break restrictions. Knowledge brings an opportunity to transform technologies and production cycle in such a way that any exhausting or expensive resource might be replaced by substitutes. Consequently, by creating initial awareness of efficient energy use, it gets possible to find solution how to ensure security of energy supply in the long term.

Pros and cons of thermodynamics theory application regarding fuel and energy resources utilization are reviewed by Bruno Fritsch, S. Schmidheiny, and W. Seifritz (1994) [8]. Scientists consider thermodynamics theory as a new route to sustainable economic growth. Building a bridge between school of thermodynamics and neoclassical growth theory, they were able to show significant links between entropy-increasing processes of energy use and growth of new business entities. These links are based on such pillars as knowledge, time and energy. If they are duly taken into account, steady growth becomes evident in the long run.

Unfortunately, knowledge can not enhance economic growth immediately. There should be new organizational patterns and links for more effective factors interaction under the frame of operating production model. In light of this, scientists propose a production model based on five input factors: capital, labor, technology, resources and environmental productivity, assuming that production output should be used not only for consumption and investment but also for investment in new technologies. They add new definitions to this model: “technology stock”, “environment productivity” and “pollution stock”. In such a manner, Fritsch, Schmidheiny, and Seifritz intend to create a new philosophy of production process in strong interaction with environment.

Another pillar is difference in time scale of technological progress and political options. It is especially evident if we consider the speed at which societies generate knowledge to accelerate transformation of energy systems to ecologically accepted targets. In some countries, it is at such a low level that additional government incentives should be used to encourage knowledge generation and using in real-case scenarios.

CONCLUSION

Sustainable economic growth is achievable on the basis of complete transformation into resource efficient, knowledge-based and low-carbon economy. Existing correlation between research and development, energy sector indicators and growth domestic product is an empirical evidence of this hypothesis. The record shows, that in Germany and the Russian Federation economic growth strongly depends on progress in energy sector development. While it correlates less to research and development. That might be explained by insufficient number of innovations in energy sector. In view of this, inventor networks appear to be the most functional mechanism for fostering technological change in renewable power generation sector. To put them into practice, government support is needed on a systematic basis.

REFERENCES

[1] World Bank (n.d.), Energy use (kg of oil equivalent per capita) [Data file]. URL: http://data.worldbank.org/topic/energy-and-mining

[2] European Commission, “A European strategy for sustainable, competitive and secure energy”. Green Paper. Brussels: Commission of the European Communities, 2006.

[3] European Commission, “Energy roadmap 2050. Impact assessement and scenario analysis”. Commission staff working paper. Brussels, 2011.

[4] European Commission, “Energy roadmap 2050”. Luxemburg: Publications Office of the European Union, 2012.

[5] IEA, “Energy and climate change”. World Energy Outlook Special Report. Paris: OECD/IEA, 2015.

[6] IEA, “World Energy Outlook 2017”. Paris: OECD/IEA, 2017.

[7] IEA, “Energy Technology Perspectives 2017” Paris: OECD/IEA, 2017.

[8] B. Fritsch , S. Schmidheiny and W. Seifritz, “Towards the ecologically sustainable growth society: physical foundations, economic transitions, and political constraints”. Berlin: Springer-Verlag, 1994.

[9] J. L. Simon, “The Ultimate resource”,. Princeton, NJ: Princeton University Press, 1996.

[10] OECD, “Conducting sustainability assessment”. OECD Sustainable Development Studies. OECD Publishing, 2008.

[11] B. Barton, S. Blackwell, G. Carrington, R. Ford, R. Lawson, J. Stephenson, P. Thorsnes, and J. Williams, “Energy Cultures: Implication for Policymakers”. Danedin: Centre for Sustainability, University of Otago, 2013.

[12] M. S. Chiu, “Tensions in implementing the “energy-conservation/carbon-reduction” policy in Taiwanese culture”, Energy Policy, vol. 55, 2013, pp. 415-425.

[13] U. Cantner, H. Graf, J. Herrmann, and M. Kalthaus, “Inventor networks in renewable energies: The influence of the policy mix in Germany”, Research Policy, vol. 45, 2016, pp.1165-1184.

[14] World Bank (n.d.), GDP per capita. [Data file]. URL: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD/countries?page=2

[15] World Bank (n.d.), Research and development expenditure (% of GDP) [Data file]. URL: http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS/countries

[16] World Bank (n.d.), Renewable electricity output (% of total electricity output) [Data file]. URL: http://data.worldbank.org/indicator/EG.ELC.RNEW.ZS/countries

[17] World Bank (n.d.), Energy intensity level of primary energy (MJ/$2011 PPP GDP) [Data file]. URL: http://data.worldbank.org/indicator/EG.EGY.PRIM.PP.KD/countries

[18] World Bank (n.d.), Energy use (kg of oil equivalent per capita) [Data file]. URL: http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries

[19] World Bank (n.d.), Patent applications, residents [Data file]. URL: http://data.worldbank.org/indicator/IP.PAT.RESD/countries

[20] World Bank (n.d.), Renewable energy consumption (% of total final energy consumption) [Data file]. URL: http://data.worldbank.org/indicator/EG.FEC.RNEW.ZS/countries