**BUCHAREST UNIVERSITY OF ECONOMIC STUDIES**

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**THE CHALLENGES OF ECONOMIC COOPERATION IN THE BLACK SEA REGION**

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**KEYWORDS**

Black Sea region, economic cooperation, regional security, wind energy, offshore, sustainable economic development.

**SUMMARY**

The main purpose of the present paper is to assess the potential for economic cooperation in the Black Sea region and to formulate strategic recommendations for its exploitation. Regional cooperation can take place in any economic field if it offers opportunities for the involved parties, but the present research focuses on identifying one of them, whose potential could support the progress and regional integration efforts of the Pontic states. Specifically, the paper analyzes the role of the energy sector in maintaining economic security and improving regional cooperation. The study takes into consideration the context of the geopolitical and military challenges in the Black Sea region and the international ideal of transition to a green and sustainable economy.

Specific objectives of the research:

* Studying the impact of security factors and geopolitical instability on economic cooperation and foreign investment.
* Historical exploration of economic cooperation in the Black Sea region.
* Evaluation of the legislative and institutional framework governing the economic cooperation in the region.
* Analysis of the economic structure and macroeconomic performance of the Black Sea states (development differences and regional convergence).
* Identification, modeling and comparison of possible scenarios for energy cooperation in the region, especially in the field of offshore renewable energy.
* Formulation of strategic recommendations for capitalizing on the energy potential of the region.

The doctoral research tested five working hypotheses regarding the barriers and opportunities of economic cooperation in the Black Sea region, with a focus on the impact of geopolitical insecurity, the role of the European Union, as well as the potential of offshore renewable energy.

The research activity started from the hypothesis that the process of development and economic integration of the Black Sea region requires a new impetus for reducing the development gap with Central and Western Europe, accumulated during the period of Soviet control. Such an opportunity is offered by renewable energy resources that can be exploited by the Pontic states through investment projects in offshore areas, but the instability of regional security constitutes the most pressing challenge.

The results of the qualitative analyses showed that the factor generating the greatest instability in the area is represented by Moscow's hostile actions aimed at maintaining or increasing its influence over neighboring countries. In addition, the Monte Carlo analysis simulating the impact of major geopolitical events on the price of natural gas (in the fifth chapter) shows that geopolitical stability and regional security are two essential factors for sustainable development and for attracting foreign direct investment.

The methodological approach of the research is interdisciplinary. It analyzes simultaneously or successively the economic aspects and the geopolitical events or facts, emphasizing their connection with military actions and the evolution of the regional energy market. In the case of the Black Sea, the economic, geopolitics and security fields are rarely separable in the research process. Such an approach was necessary to ensure a complete framework of the analysis, so that the final results and recommendations are as well-founded and realistically applicable as possible.

The research methodology used to achieve the objectives proposed in the paper was a mixed one, which combined quantitative analysis methods (such as correlation analysis, integrated autoregressive moving averages, heteroscedastic models, etc.) with qualitative ones (documentary and legislative analysis, strategic evaluation tools such as SWOT and PESTEL, scenario analysis, etc). The methods applied provided the analytical relevance necessary to validate the results obtained and to ensure the viability of the conclusions formulated.

Quantitative analysis was useful, mainly for obtaining robust and objective conclusions regarding the economic situation of the Black Sea region states, but also for concretely analyzing the opportunities offered by the potential of the offshore area as an enhancing factor for regional cooperation. A major advantage of these methods lies in the possibility of comparing the results obtained in the same reference system (even if data normalization is necessary), as well as the possibility of modeling the data sets so that they can be comparable.

The qualitative analysis methods aimed to capitalize on or explain the results obtained through the quantitative ones and support the research hypotheses for outlining the strategic context in the Black Sea region. Through them, the legislative framework was analyzed, the main possible geopolitical and military scenarios were identified, and the final recommendations of the paper were argued.

The methodological design was useful for obtaining concrete and viable results for formulating opinions and realistic recommendations that can be relevant for making decisions regarding regional economic development. The combination of qualitative and quantitative methods ensured the possibility of approaching the economic dimension of the region, simultaneously with the military and geopolitical ones, providing an overview of the state of affairs.

The first analysis of the Black Sea trade network showed that it is no longer a central point for European trade, although it is located at the confluence of the Middle East, Central Asia and Europe. This analysis studied the centrality of intermediation and the Eigenvector centrality, based on data on bilateral trade flows between all Pontic countries and between them and the European Union. The conclusion of the approach was that the Black Sea has become a peripheral node of international trade, and countries with high economic power, such as the Russian Federation and Turkey, are the ends of the line for regional trade, representing either sources or destinations of goods flows, or exit gates for goods produced in the Pontic area. In addition, trade between the analyzed states is lower than that between them and the outside of the region, with a high dependence on the international trade network, but not an interdependence with it.

In this context, after identifying the historical causes of the challenges currently encountered, possible solutions to the problems that were found in the economic development initiatives were tested. Thus, it was found that a central role in the work is occupied by studying the relations between the Pontic countries and the European Union, in contrast to the Russian influence in the region. The situation of the energy sector and the economic development options based on it are also analyzed – the exploitation of offshore natural gas perimeters and the production of renewable energy in the Pontic states.

A few heat maps were created to group the Pontic states according to their economic characteristics, and to highlight the identified specifications, hierarchical clusters were created using a K-Means diagram and principal components analysis (PCA) on three dimensions (explaining 78% of the model). Also, to assess their economic stability prospects, an equation was created with the economic indicators considered relevant, which was applied for each state, calculating a score for the short-term economic stability perspective.

Subsequently, the perception of society on the European path was analyzed simultaneously with that on the Russian influence in the Black Sea region, in order to evaluate the trends of economic integration - as opposed to those of fragmentation. To achieve this goal, a web scraping was carried out, with the application of the evaluation of the sentiment created by them through the Natural Language Toolkit, using the Python software program.

The analysis of the opportunities offered by the energy sector for regional economic cooperation began by estimating the total natural gas consumption in 2024 and 2025, using an ARIMA (1,1,1) model. Subsequently, by applying the Monte Carlo method (with 60,000 possible scenarios) it was tested how the price of natural gas could be affected by geopolitical developments and events in the Black Sea region. A PESTEL analysis was also carried out, as well as a SWOT one for the regional energy sector, in order to highlight the investment opportunities and risks.

The part addressing the opportunity offered by the access to offshore renewable energy resources began by identifying solutions to its main challenge for the energy system – volatility. In this context, an EGARCH (1,1) model and two machine learning models (Random Forest Regressor and Extreme Gradient/XG Boost) were tested as solutions to increase the predictability of wind energy production.

The main component of the thesis consisted in testing the profitability of wind energy production of 4 wind turbine models, in the offshore area of ​​the Black Sea (in Romania, Bulgaria and Turkey). For this purpose, polar diagrams were made regarding the speed, direction and time interval of the wind in 8 points located at distances of 50-100 km from each other. Based on the mentioned data, scenarios regarding the investment and operation costs of offshore wind farms were modeled for several possible scenarios, the result being the estimation of the levelized cost of energy production (LCOE).

Table 1. Levelized cost of offshore wind energy production in the Black Sea.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Production (euro/MWh) | | | | | |
|  | Minimum | | Medium | | Maximum | |
|  | CAPEX 2200 euro/kW | CAPEX 3400 euro/kW | CAPEX 2200 euro/kW | CAPEX 3400 euro/kW | CAPEX 2200 euro/kW | CAPEX 3400 euro/kW |
| LCOE SG 14-236 DD | Sulina | 91,08 | 122,49 | 61,07 | 81,13 | 43,77 | 57,3 |
| Jurilovca | 107,89 | 145,64 | 70,39 | 93,96 | 49,16 | 64,71 |
| Capul Midia | 93,07 | 125,22 | 62.04 | 82,46 | 44,21 | 57,9 |
| Vama Veche | 82,08 | 110,08 | 55,58 | 74,94 | 41,67 | 54,4 |
| Georgi | 118,43 | 160,17 | 75,09 | 100,45 | 50,43 | 66,47 |
| Nos Emine | 60,76 | 80,7 | 45,59 | 59,8 | 36,45 | 47,2 |
| Sinemorets | 95,59 | 128,7 | 64,09 | 85,3 | 45,75 | 60,02 |
| Çilingozçiftliği | 75,6 | 101,16 | 53,36 | 70,5 | 40,15 | 52,3 |
| LCOE GE Haliade-X | Sulina | 89,5 | 120,3 | 60,19 | 79,92 | 38,66 | 50,25 |
| Jurilovca | 105,69 | 142,62 | 69,45 | 92,68 | 48,32 | 63,56 |
| Capul Midia | 91,28 | 122,75 | 61,1 | 81,17 | 43,53 | 56,95 |
| Vama Veche | 80,57 | 108 | 55,77 | 73,83 | 41,06 | 53,55 |
| Georgi | 116,86 | 158 | 73,69 | 98,52 | 49,64 | 65,38 |
| Nos Emine | 59,84 | 79,43 | 45,08 | 59,09 | 36,01 | 46,6 |
| Sinemorets | 94,10 | 126,64 | 63,28 | 84,09 | 45,08 | 59,09 |
| Çilingozçiftliği | 74,26 | 99,3 | 52,69 | 69,58 | 39,62 | 51,57 |
| LCOE Vestas V236 | Sulina | 96,6 | 130,09 | 64,36 | 85,66 | 46,02 | 60,39 |
| Jurilovca | 114,42 | 154,65 | 74,38 | 99,46 | 51,69 | 68,21 |
| Capul Midia | 98,28 | 132,41 | 65,38 | 87,06 | 46,49 | 61,03 |
| Vama Veche | 86,72 | 116,47 | 59,47 | 78,95 | 43,67 | 57,16 |
| Georgi | 126,32 | 171,04 | 79,35 | 106,31 | 53,14 | 70,2 |
| Nos Emine | 63,7 | 84,75 | 47,46 | 62,24 | 37,81 | 49,08 |
| Sinemorets | 100,93 | 136,05 | 67,35 | 89,78 | 48,02 | 63,15 |
| Çilingozçiftliği | 79,89 | 107,06 | 55,86 | 73,95 | 41,96 | 54,79 |
| LCOE MingYang MySE 12-242 | Sulina | 75,43 | 100,92 | 51,54 | 68 | 37,25 | 48,31 |
| Jurilovca | 88,63 | 119,11 | 58,97 | 78,23 | 41,49 | 54,15 |
| Capul Midia | 76,96 | 103,02 | 52,3 | 69,04 | 37,59 | 48,77 |
| Vama Veche | 68,24 | 91 | 48,32 | 63,56 | 35,71 | 46,18 |
| Georgi | 97,65 | 131,53 | 62,43 | 83 | 42,48 | 55,51 |
| Nos Emine | 51,79 | 68,34 | 40,43 | 52,68 | 32,15 | 41,28 |
| Sinemorets | 79,21 | 106,13 | 54,46 | 72,02 | 39,04 | 50,77 |
| Çilingozçiftliği | 63,21 | 84,09 | 46,1 | 60,50 | 34,74 | 44,84 |

Source: Tables 6.1.3, 6.1.4, 6.1.5 and 6.1.6 from the doctoral thesis

The results in the final table show that the offshore area of ​​the North-West Black Sea is favorable for the creation of wind farms, the LCOE being competitive for the European market, and the risk that the investment will pay off in too long a time is very low. For cases where CAPEX and production are at an average level, the investment is profitable for each of the technologies analyzed, the LCOE being in almost all cases (about 80%) between 54 euro/MWh and 91 euro/MWh.

The only scenario in which the LCOE can exceed the mentioned range in most cases is the one in which the investment reaches the maximum limit (3400 euro/kW) while the production records the minimum values. However, even in the pessimistic scenario, the LCOE records values ​​that can be profitable, being well below those of nuclear energy production (136 euro/MWh – 490 euro/MWh) and biogas (201 euro/MWh – 325 euro/MWh).

Finally, the paper also involves recommendations for the authorities in the Pontic states which are responsible for improving the region's competitiveness at the European level. Among these, the most important are:

* finalizing the necessary legislative framework in Romania and Bulgaria for offshore energy production and implementing the CFD system, following the British and Polish model to reduce the risk of price fluctuations and encourage investments in renewable energy.
* focusing the strategy for developing the domestic electricity transmission network on the infrastructure located in the coastal area and increasing the regional interconnectivity (through projects like the submarine cable between Romania and Georgia, which can improve the possibilities of balancing the systems through imports and exports);
* establishing (with the participation of the state’s institutions) investment funds in the energy field (in which financial institutions, energy suppliers and producers could participate) intended to attract foreign direct investment in the expansion of the transport infrastructure, simultaneously with the development of new production capacities.
* jointly planning the future investments, so that, in the long term, the development of the energy transport infrastructure to create a ring around the Black Sea, which would support the growth of renewable energy production in each state involved.

The conclusions of the doctoral research support these recommendations towards the formulation of public policies for sustainable energy development, indicating offshore wind energy as a vector of regional cooperation.