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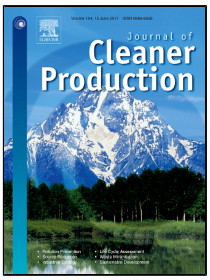

Assessment of sustainable development of hard coal mining industry in Poland with use of bootstrap sampling and copula-based Monte Carlo simulation

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Assessment of sustainable development of hard coal mining industry in Poland with use of bootstrap sampling and copula-based Monte Carlo simulation

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Abstract

The aim of the research was to develop an integrated model and assess the level of sustainable development of hard coal mining industry in Poland. The analyzes were performed using multi-criteria decision-making method (AHP), Monte Carlo simulation, bootstrap technique, empirical copula, and frequency distributions. Spearman's correlation coefficients under uncertainty were also examined. To mitigate the impact of the indicators strongly correlated we adopted matrix transformation in order to estimate the sub-correlation aggregates. In total, 24 criteria were included; economic, environmental, and social aspects of the problem were analyzed.

As a result of the simulation, Spearman's rank correlation coefficients were estimated. The variability of the estimated sustainability index between 5% and 95% percentile in their distributions does not exceed 110% of the mean. The estimated location and spread statistics and mean value errors are acceptable while the estimation of the sustainable development based on average values is reliable. There is a 90% probability that, in the perspective of 2020, the trend of the majority of aggregated sustainability indicators will be horizontal, while the coal production will be stable, in the range between 65 and 75 million Mg per year.

The obtained results have shown limited improvement of sustainable development of hard coal mining industry in Poland in the analyzed period (an upward trend in the period 2007-2013 and a decline in following years). The highest increase of aggregate indicator in 2007-2016 period was recorded for the economic dimension (10.4%), which is mainly a consequence of increasing production of coking coal and revenues. In the same time total bituminous coal production in Poland was reduced by 19.5%. In the environmental and social dimensions, the indicators show a downward trend (falling by a total of 4.0% and 5.5% by 2016).

Keywords: hard coal mining industry, sustainable development, AHP model, Monte Carlo simulation, bootstrap, empirical copula, Spearman's rank correlation.

1. Introduction and justification of the expediency of the works undertaken

Energy is the basis of human functioning in almost all areas of economic activity. Its acquisition, processing and use helped to achieve the present level of development of the economy and civilization. Almost 87% of the energy in the world is generated by the combustion of fossil fuels, of which about 30% is coal (BP, 2015).

The advantage of coal over other fossil energy resources is its prevalence. Even though coal is often ousted by natural gas, its consumption, despite its reduced share in the global energy balance, will continue to grow. This is due to the increasing demand for energy. Long-term

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