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Energy price transmission on prices of cement and iron production in EURO 19 EU countries

Mullen Jan Kevin

Czech University of Life Sciences Prague, Prague, Czechia

(E-mail: mullen@pef.czu.cz)

Abstract. The article focuses on the transmission of energy prices to cement and steel prices. No significant investigations have been done on this focused area. An exploration of similar scientific articles has been performed, mainly focusing on the energy efficiency of cement production and iron/steel production. Furthermore, key articles focusing on energy price transmission were investigated. Using indexes for the EURO 19 data for producer prices for energy, cement, and iron/steel, an investigation was performed to see if these variables are cointegrated. During the analysis, the augmented Dickey-Fuller test, Johannsen test, and Vector error correction model were used. The results revealed that energy and steel prices are strongly cointegrated, indicating a long-term equilibrium relationship, whereas cement prices demonstrated non-stationarity and no significant long-term linkage. The VECM confirmed that deviations from equilibrium between energy and steel prices are corrected over time, suggesting a flexible yet stable price relationship. This highlights the critical role of energy prices as a determinant of steel production costs, with implications for construction sector competitiveness and cost structures across the EU. These results may be used by policymakers or stakeholders of given industries.

Keywords: Energy production prices, iron production prices, cointegration, VECM

Introduction

The prices of energy, cement, and iron/steel are critical components of the construction industry in Europe. These producer prices can have significant impacts on the cost of construction and, as such, have an impact on the broader economy. Therefore, understanding the dynamics of the relationship between these producer prices is of great importance to investors, industry stakeholders, and business plans. This may also influence EU policymakers in view of the EU´s green deal.

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As part of the green deal, industries will be encouraged to extensive use of renewable sources of energy, which should decrease the carbon footprint. This is a crucial aspect, because buildings construction and operations are responsible for up to 40% of Europe´s total energy consumption and consequently the corresponding carbon footprint, as provided by (EU Energy performance of buildings directive, 2024). In view of this, it is necessary to understand this relationship of the transmission of energy prices to the prices of cement and iron/steel. Energy is a major input in the production processes of cement and iron/steel, which implies that any change in energy producer prices can have a significant effect on the production costs of these construction materials. This may be apparent in the large increase in costs of construction in the past few years, during which energy prices skyrocketed.

Understanding this relationship may provide insights that could be applied to investment analysis for the use of cheap renewable sources of energy, such as wind energy or photovoltaics, in the production process. This could lead to a decrease in producer prices for cements and iron/steel, as well as a decrease in the total carbon footprint linked to the construction industry. As a result, if renewable sources of energy are fully implemented in these industries, it could allow for better competition outside of the European Union as well as decreasing the prices of constructions within the EU, which would help finance the green deal real estate transformation.

Applying the theory of price transmission from energy prices to producer prices of cement and steel in Europe from January 2000 to January 2023, it is possible to investigate the extent to which changes in the prices of energy result in changes in cement and iron/steel producer prices. These may be viewed as inputs to total construction costs. Cointegration analysis can be used to examine the long-term relationship between the producer price of energy input and the producer prices of cement and iron/steel of construction output, while Vector Error Correction Models (VECM) can be used to analyze the short-term dynamics of price transmission.

From the results of this study, the relationship between energy prices and prices of iron/steel is clearly apparent. The results of ADF test for cement prices indicated non-stationarity, and further testing was not performed. The Johansen results for energy prices and iron/steel prices indicated one cointegration. The VECM test for the same variables indicated both a short-run and long-run relationship between the two variables.

Literature review

No papers were found that would deal specifically with price transmission between energy and cement and energy and iron/steel. However, numerous studies deal with cement industry and its energy use and emissions, such as (Morrow et al, 2014). The cement industry is inherently tied to the energy sector due to its extensive energy consumption. (Ke et al., 2012) analyze cement production in China. In 2010, China was the world's leading producer of cement, contributing 56% to global cement production with an output of 1.9 billion tons. This massive production volume resulted in an estimated CO_2 emission exceeding 1.2 billion tons, underlining the critical necessity to accurately understand and quantify cement-related emissions within China. (Ke et al.,2012) also explores the prevailing trends in energy usage and carbon dioxide (CO_2) emissions within China's cement industry. These trends serve as the foundation for constructing models that project various levels of cement production, efficiency improvement, and carbon reduction from 2011 to 2030. The study develops three distinct forecasts for cement output, each derived from an analysis of past production data and key factors including physical conditions and macroeconomic indicators.

(TALAEI et al., 2019) deal in their paper with the cement industry in Canada and analyzes using different scenarios possible energy use and carbon paths for Canadian industry. The paper´s authors also investigated the possible savings and concluded that more than 70% emission reduction is achievable with negative costs.

Likewise, there are a number of studies which focus on iron/steel production and the relationship energy has with this metal productions. (Flues et al., 2015) investigated the specific factors which were associated with energy consumption and how this may affect the total steel production. (Padro and Moya, 2013) have also investigated the iron steel production in terms of energy efficiency, where they developed two alternative scenarios with energy efficiency technologies applied and modeled the energy reductions. Further studies investigating energy efficiency and CO2 emissions of the state iron/steel production, have been published for other countries, such as (Worrel et. al., 2001) for the United States, (Hasanbeigi et. al., 2013) for China, or (Morrow et. al., 2014) for India. In another article, the authors investigate the effects of price transmission from steel prices between different products and the midstream industry chain. (Guo et. al., 2019) conclude which types of metal products transfer the highest price.

There have been several studies of energy price transmissions with a focus on different areas of price transmission. The study of (Tiwari et. al., 2020) investigates the price transmission between fuel and the following variables: food prices, industrial prices, and metal prices. (Martín-Moreno et. al., 2019) investigate fuel price transmission in the European Union market and apply TAR-ECM and Markov-switching approach. These articles may be the most similar to our study; however, our study is based on newer data that includes the European energy crisis, as well as using different investigative methods.

Methodology

Data on monthly producer price indexes of steel, cement, and energy in Europe´s Euro 19 countries were collected from January 2000 to January 2023 from Ref. To ensure consistency in the used data, all data sets were for domestic sales, with the same unit of 100% being for 2015. All three datasets were obtained from the European Central Bank´s datasets (Euro area 19, 2023)

Unit root test

At the beginning of this analysis, a unit root test using the ADF test is conducted to assess the stationarity of the variables – energy, cement, and steel. The ADF test is a widely used method for testing the presence of unit roots in time series data, which can indicate non-stationarity and the possibility of spurious regressions. The ADF test will be used to test the null hypothesis that the variables are nonstationary against the alternative hypothesis that the variables are stationary after appropriate differencing, as provided by (Greene William, 2018).

Augmented Dickey Fuller

The standard version of the ADF test treats the alternative hypothesis as stationary. The basic structure, described (Greene William, 2018), of the ADF test is as follows:

Equation (1):

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \delta 1 \Delta Y_{t-1} + \delta 2 \Delta Y_{t-2} + ... + \delta k \Delta Y_{t-k} + + \varepsilon_t \quad (1)$$

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where:
– ΔY_t is the first difference of the series
– t is the trend
– Y_{t-1} is the lagged value of the series
– $\Delta Y_{t-1}, \Delta Y_{t-2}, ..., \Delta Y_{t-k}$ are the first differences of past values
– ε_t is the error term
– $\alpha, \beta, \gamma, \delta 1, \delta 2, ..., \delta k$ are parameters to be estimated.
The null hypothesis (H0) and alternative hypothesis (H1) are defined as:
H0: $\gamma = 0$ (The time series has a unit root, i.e., it is non-stationary)
H1: $\gamma < 0$ (The time series does not have a unit root, i.e., it is stationary)

In the next step we conducted an assessment of cointegration among the factors through the utilization of the Johansen test, which is a commonly employed technique for evaluating the presence of cointegration among several time series variables. The Johansen test shall be employed to examine the hypothesis that there is no cointegration among the variables, and contrast it with the alternative hypothesis that there is at least one cointegrating relationship. The quantity of cointegrating vectors will be determined based on the outcome of the Johansen test. The Johansen test involves the estimation of a VAR model with a set amount of lags, followed by the computation of the eigenvalues and eigenvectors of the ensuing covariance matrix. The test statistic is founded on the highest eigenvalue or trace of the matrix of test statistics, and the null hypothesis is that there is no cointegration among the variables, as described by (Greene William, 2018).

Johansen test is defined as follows:
Equation (1):

$$\Delta X_t = \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + ... + \Gamma_{p-1} \Delta X_{t-p+1} + \mu + \varepsilon_t \quad (2)$$

where:
– X_t is a k x 1 vector of variables that are integrated of order one
– μ is a deterministic term
– ε_t is a k x 1 vector of error terms
– Π is a k x k matrix of coefficients to be estimated
– Γ_i is a k x k matrix of coefficients to be estimated
– Δ is the first difference operator
– t is the time period
The Johansen test employs two test statistics:
The trace statistic:
Equation (2):

$$\lambda_{trace} = -T \Sigma_{i=r+1}^{k} \ln(1 - \lambda_i) \quad (3)$$

The max-eigenvalue statistic:
Equation (3):

$$\lambda_{max} = -T \ln(1 - \lambda_{r+1}) \quad (4)$$

where:
– λ_i are the eigenvalues obtained from the estimated Π matrix in descending order
– T is the number of useful observations (after adjustments for lags)
– r is the number of cointegrating vectors under the null hypothesis

Initially, VECM model is used to examine the short-run and long-run dynamics among the variables.

The Vector Error Correction Model (VECM) is a commonly used technique in time series analysis that allows for the investigation of both short-run dynamics and long-run equilibrium relationships among multiple nonstationary time series variables. The VECM is an extension of the Vector Autoregression (VAR) model, which allows for the inclusion of cointegrated variables in the system. The VECM involves estimating an error correction model, which captures the adjustment process that occurs when the variables deviate from their long-run equilibrium relationship. The VECM has two components: the short-run dynamics captured by the lagged differences of the variables, and the long-run equilibrium relationship captured by the error correction term. The error correction term is estimated based on the cointegrating relationship(s) identified by the Johansen test. The VECM is estimated using maximum likelihood estimation, and the lag lengths are chosen based on information criteria such as the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC), as described by (Greene William, 2018).

The VECM can be specified as follows:

Equation (1):

$$\Delta X_t = \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + ... + \Gamma_{p-1} \Delta X_{t-p+1} + \mu + \varepsilon_t \quad (5)$$

where:

– ΔX_t is the first difference of the time series X at time t

– X_{t-1} is the matrix of variables lagged once

– ΠX_{t-1} is the error correction term where Π is the matrix that includes the speed of adjustment parameters and the cointegrating vectors

– Γ_i are (k x k) matrices of coefficients of the lagged differences of the dependent variables

– μ is a deterministic term

– ε_t is a vector of error terms

The term ΠX_{t-1} is the error correction term. It corrects the previous period's disequilibrium or error. The rank of Π gives the number of cointegrating relationships.

The $\Gamma_i \Delta X_{t-i}$ terms represent the short-run dynamics of the model. They allow the model to include short-run effects of changes in Y on changes in X.

In vecm, the Π matrix is decomposed into α and β, where α represents the speed of adjustment parameters and β contains the cointegrating vectors.

Results

The data analysis was performed using the GRETL software. The data presentation was performed by the author

Table 1. Basic descriptive statistics

			standard		
	mean value	median	deviation	Min	Max
index cement prices	95,87	98,1	15,34	74,2	169,1

index steel prices	107,7	107,3	29,02	64,1	219,6
index energy prices	103,4	100,9	32,12	57,2	225,5
	variation		standard		
	coefficient	Slant	sharpness	5%	95%
index cement prices	16001	1,4386	4,4037	76,39	123,01
index steel prices	0,26948	1,32	2,9076	67,4	175,6
index energy prices	0,31068	1,035	1,6768	61,305	150,73

Source: own calculations

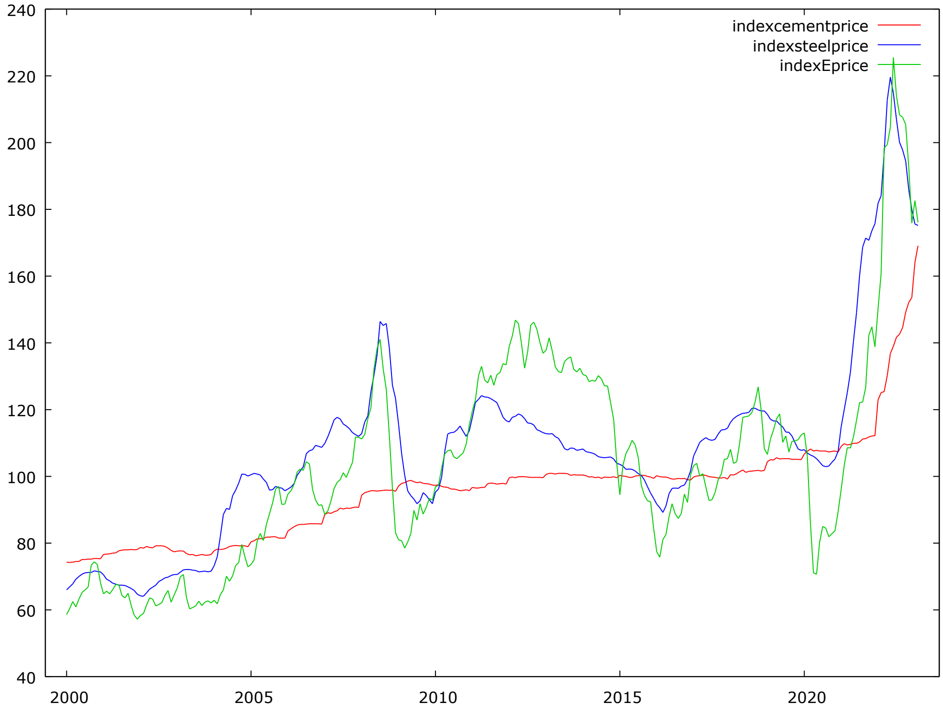

Figure 1 Timeline graph of variables

Source: own calculations

4.2 Stationarity test

First, Augmented Dickey fuller was estimated to determine stationarity of the time series.

As the first variable, steel was tested for the presence of a unit root. Results are presented in Table 2 below.

Table 2. Augmented Dickey-Fuller test for energy index prices, cement index prices, and steel index price with testing down from lag 3

	Cement index P	Steel index P	Energy index prices
p-value	1	0,5294	0,4454

estimated value (a-1)	0,0188388	-0,00653015	-0,0160124
autocorrelation koef.	-0,048	0,003	0,003
tau_c	3,54181	-1,50882	-1,67244

Source: own calculations

When the p-value from the Augmented Dickey-Fuller (ADF) test is greater than 0.05, it suggests that the data may be characterized by a unit root. As all ADF tests have a p-value greater than 0.05, we can proceed to cointegration test using Johansen procedure.

However, the cement price results indicate a positive tau value, which indicates a "explosiveness" of the data, in other words, non-stationarity. For this reason, further analysis for cement prices has not been performed. Furthermore, having a p-value of 1 for cement also suggests changes due to random chance.

Cointegration analysis

Johansen tests were conducted for the analysis of the long-run relationships between cement prices, steel prices and energy prices, as the purpose is not to determine a possible relationship between cement and steel.

Firstly, Johansen test was conducted for cement and energy prices, with results presented in Table 3. Johansen test was also conducted for steel index prices and energy index prices in Table 4.

Table 3. Johansen test for the cement index price and energy index price.

Johansen test			
energy price and cement price			
matrix value of p-values			
0	0,12452	40,998 [0,0000]	36,572 [0,0000]
1	0,015965	4,4259 [0,0354]	4,4259 [0,0354]
Beta cointegrations vector			
Energy price		0,026229	0,051742
Cement price		0,02862	-0,12585
Alfa adjustment vector			
Energy price		-0,87595	-0,53966
Cement price		0,32336	-0,079744
Matrix of long-term effects (alfa*beta)			
Energy price		Cement price	
Energy price		-0,050899	0,042847
Cement price		0,0043554	0,01929

Source: own calculations

Table 4. Johansen test for steel index price and energy index price.

Johansen test			
energy price and steel price			
matrix value of p-values			
0	0,043808	16,915 [0,0287]	12,319 [0,0989]
1	0,016574	4,5962 [0,0320]	4,5962 [0,0320]
Beta cointegrations vector			
Energy price		-0,070588	0,0016596
Steel price		0,070382	-0,12585
Alfa adjustment vector			
Energy price		1,0149	0,062908
Steel price		0,14794	-0,23332
Matrix of long-term effects (alfa*beta)			
Energy price		Steel price	
Energy price		-0,071537	0,073591
Steel price		-0,01083	0,0024082

Source: own calculations

Results of the Johansen test for steel and energy indicate that there is one cointegrating relationship between the analyzed variables of steel index price and energy index price.

Vector error correction model

In the next step, VECM model is estimated, results are presented in Tables 5 and 6 for the steel index prices and energy index prices. The model for VECM for cement index prices and energy index prices was not performed, as the results from the Augmented Dickey Fuller and Johansen test

Table 5. VECM test for steel index price and energy index price.

Vector error correction model		
beta cointegration vector	alpha adjusted factor	
Energy price	1	-0,07164
steel price	-0,99709	-0,010443
AIC	10,1567	
BIC	10,3408	
HQC	10,2306	

Source: own calculations

Table 6. VECM test for steel index price and energy index price

	Equation 1: d_indexEprice				
	coeficient	standard error	t-ratio	p-value	
const	-0,117034	0,302997	-0,3863	0,6996	
d_indexEprice_1	0,294907	0,0621117	4,748	3,34E-06	***
d_indexEprice_2	-0,0578031	0,0648784	-0,8909	0,3738	
d_indexsteelpr~_1	0,381038	0,154582	2,465	0,0143	**
d_indexsteelpr~_2	-0,0306072	0,149461	-0,2048	0,8379	
EC1	-0,0716415	0,0205154	-3,392	0,0006	***
	Equation 2: d_indexsteelprice				
	coeficient	standard error	t-ratio	p-value	
const	0,0649586	0,123291	0,5269	0,5987	
d_indexEprice_1	0,0910009	0,0252736	3,601	4,00E-04	***
d_indexEprice_2	0,038212	0,0263994	1,447	0,1489	
d_indexsteelpr~_1	0,727459	0,0629002	11,57	2,22E-25	***
d_indexsteelpr~_2	-0,145717	0,0608164	-2,396	0,0173	**
EC1	-0,0104427	0,00834783	-1,251	0,212	

Source: own calculations

The findings indicate that there exists correlation between the production prices of iron/steel and energy production prices, where the energy prices have a negative effect on the price of steel. The short-term dynamics suggest that deviations from the long-term equilibrium are rectified over time, implying that the correlation is flexible and responsive to market changes.

Results indicate that the alpha value for steel is -0,010443, while the alpha value for energy is -0,07164. These figures signify the rate at which the variables return to their long-term equilibrium. The error correction parameter for steel indicates that in case of any deviation from the long-term equilibrium, the steel value changes at a slower speed in comparison to energy value, considering that the alpha value for energy is greater. Likewise, the error correction parameter for energy implies that the energy value adjusts at a quicker pace in comparison to cement value.

The statistical values for the delayed coefficients imply that there exists immediate-term fluctuations among the factors. More specifically, with regard to steel, the initial delay holds importance and for energy, the initial delay is also significant. The meaningful delays signify that there is a correlation between previous values of the factors and their current values, which indicates that they have an impact on each other in the immediate term.

Discussion

The results may be viewed as rudimentary data for further analysis or for investment plans and analysis, which could be used for policymakers' decision-making processes. However, a more extensive use of specific data for individual variables for individual countries of the European Union would yield more targeted results, which would also incorporate the local energy mix. As such, it would be easier to extend the data by the potential carbon footprint for individual productions.

Another point of further investigation could be the effect of energy price change on aggregate construction costs for given countries. However, the limiting factor of such analysis would be the availability of data for the breakdown of the aggregate construction cost. This will require collaboration with an expert in construction costing.

Conclusion

Based on the analysis presented in this paper, we have found strong evidence of a long-run relationship between energy prices and steel. The results of Augmented Dickey-Fuller test for cement prices indicated non-stationarity. Our results suggest that the two variables, energy prices and iron/steel prices, are cointegrated, indicating that they share a long-run equilibrium relationship.

Results of this study show the importance of energy prices in determining the price inputs of key building materials such as iron/steel. The results may be useful for policymakers, investors, and other stakeholders in the field and who are interested in using these dynamics in industry. Future research could explore the short-run dynamics of these relationships and investigate the impact of other economic, political, and environmental factors on the energy price transmission on prices of iron and steel, such as applied carbon emission taxes.

Conflict of interest. The authors declare no conflict of interest.

Authors' contributions. The author is the sole contributor to the conception, research, and writing of this article.

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Mullen Jan Kevin

Чешский университет природных наук, Прага, Чехия

Трансмиссия цен на энергоносители на цены производства цемента и стали. Опыт 19 стран Евросоюза

Аннотация. Статья посвящена исследованию трансмиссии цен на энергоносители к ценам на цемент и сталь. В данной области ранее не проводилось значительных исследований. Проведен анализ аналогичных научных публикаций, преимущественно сосредоточенных на энергоэффективности производства цемента и чугуна/стали. Кроме того, рассмотрены ключевые работы, изучающие передачу цен на энергоносители. Используя индексы по данным EURO 19 о ценах производителей на энергоносители, цемент и железо/сталь, было проведено исследование на предмет наличия коинтеграции этих переменных. В ходе анализа применялись дополненный тест Дикки–Фуллера, тест Йохансена и векторная модель коррекции ошибок (VECM). Результаты показали наличие сильной коинтеграции между ценами на энергоносители и сталь, что свидетельствует о долгосрочной равновесной зависимости, тогда как цены на цемент оказались нестационарными и не продемонстрировали значимой долгосрочной связи. Модель VECM подтвердила, что отклонения от равновесия между ценами на энергоносители и сталь корректируются со временем, что указывает на гибкую и в то же время устойчивую зависимость. Это подчеркивает ключевую роль цен на энергоносители как фактора, определяющего себестоимость производства стали, что оказывает влияние на конкурентоспособность строительного сектора и структуру издержек в ЕС. Полученные результаты могут быть исполь-зованы разработчиками политики или заинтересованными сторонами соответствующих отраслей.

Ключевые слова: Цены на производство энергии, цены на производство стали, коинтеграция, VECM

Mullen Jan Kevin
Прагадағы Чехия өмір туралы ғылымдар университеті, Прага, Чехия

Энергия бағасының өзгерістерінің цемент пен темір өндірісі бағаларына берілуі (Еуроаймақтың 19 елі бойынша)

Аңдатпа. Мақалада энергия бағаларының цемент пен болат бағаларына берілуі зерттеледі. Бұл салада айтарлықтай зерттеулер бұрын жүргізілмеген. Цемент және шойын/болат өндірісінің энергия тиімділігіне бағытталған ғылыми мақалалар талданды. Сонымен қатар, энергия бағаларының берілуін қарастыратын негізгі еңбектер де зерделенді. EURO 19 елдері бойынша энергия, цемент және болат өндірушілерінің бағалары индексін пайдалана отырып, осы айнымалылардың коинтеграциясы тексерілді. Талдау барысында толықтырылған Дики–Фуллер тесті, Йохансен тесті және векторлық қателерді түзету моделі (VECM) қолданылды. Нәтижелер энергия мен болат бағалары арасында күшті коинтеграция бар екенін көрсетті, бұл олардың ұзақ мерзімді тепе-теңдік байланысын білдіреді, ал цемент бағалары стационарлы емес болып шықты және елеулі ұзақ мерзімді байланыс анықталмады. VECM нәтижелері энергия мен болат бағалары арасындағы тепе-теңдіктен ауытқулар уақыт өте келе түзелетінін растады, бұл олардың икемді әрі тұрақты тәуелділігін көрсетеді. Бұл жағдай энергия бағаларының болат өндірісі шығындарының негізгі анықтаушы факторы ретіндегі рөлін айқындайды және ЕО аясындағы құрылыс секторының бәсекеге қабілеттілігіне әрі шығындар құрылымына әсер етеді. Алынған нәтижелер саясат жасаушылар мен салалық мүдделі тараптар үшін пайдалы болуы мүмкін.

Түйін сөздер: энергия өндірісі бағалары, болат өндірісі бағалары, коинтеграция, VECM.

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Information about authors:

Mullen J.K. **–** corresponding author, PhD, Researcher, Faculty of Economics and Management, Czech University of Life Sciences Prague, Kamycka Street, 129, 16500, Prague, Czechia.

Mullen J.K. **–** автор для корреспонденции, PhD, исследователь, факультет экономики и менеджмента, Чешский университет наук о жизни в Праге, ул. Камыцка, 129, 16500, Прага, Чехия.

Mullen J.K. **–** хат-хабар авторы, PhD, зерттеуші, экономика және менеджмент факультеті, Прагадағы Чехия өмір туралы ғылымдар университеті, Қамыцка көшесі, 129, 16500, Прага, Чехия