

Ministry of Education and Science of Ukraine

# ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of  
Student Scientific Works

# BLACK SEA SCIENCE 2023

## PROCEEDINGS



ODESA, ONUT 2023

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# **BLACK SEA SCIENCE 2023**

**Proceedings**

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**THE SOCIO-ECONOMIC DETERMINANTS OF GREEN BOND ISSUANCE****Author:** Avhusta Hrytsenko**Advisor:** Kostiantyn Hrytsenko  
Sumy State University (Ukraine)

***Summary.** Global awareness of the climate change risks draws society's attention to issues of financing environmentally friendly projects. In this context, "green" bonds are a new financial instrument used exclusively for financing environmentally friendly projects. A wide range of issuers, from small firms to international corporations, can use "green" bonds to raise funds for environmentally friendly projects. In recent years, the "green" bonds market has been developing rapidly in the world. Financing the recovery of Ukraine after the Russian invasion requires launching this market in Ukraine as well. This will increase the scope of infrastructure projects financing in the field of alternative energy and energy efficiency, reduce greenhouse gas emissions and consumption of fuel and energy resources, and improve Ukraine's investment attractiveness and competitiveness. The "green" bond market operates under the influence of numerous factors that have both direct and indirect effects on it. The research examines the relationship between the volume of "green" bond issuance in the different countries in 2021, when its jump-like growth took place, and the factors that characterize the environmental, social, governance and macroeconomic spheres of the countries. The research was conducted on the dataset of socio-economic indicators of 54 countries. The obtained results of the study indicate that countries with a higher volume of "green" bond issuance are primarily characterized by good credit ratings, which increases investor confidence, better economic development and a large population. Understanding the socio-economic determinants of "green" bond issuance will help market participants make informed decisions.*

***Keywords:** sustainability, "green" bonds, issuance, socio-economic determinants, correlation and regression analysis.*

**I. INTRODUCTION**

The transition to a low-carbon economy requires significant investments, so the attention is focused on finding financial sources to fund environmentally friendly projects. Issuance of "green" bonds is an alternative to traditional sources of financing such projects. The International Capital Market Association defines "green" bonds as a bond instrument where the proceeds will be exclusively applied to finance or refinance, in part or full, new, or existing eligible green projects. These eligible "green" projects refer to the follows: renewable energy, energy efficiency, pollution prevention and control, environmentally sustainable management of living natural resources and land use, terrestrial and aquatic biodiversity conservation, clean transportation, sustainable water and wastewater management, climate change adaptation, eco-efficient and circular economy adapted products, production technologies, and processes and green buildings [1]. According to this definition, a wide range of issuers,

from small firms to international corporations, can use "green" bonds to attract funds for environmentally friendly projects.

In 2021, the global "green" bond market grew by 75% compared to 2020 and reached \$578 billion (Fig.1).

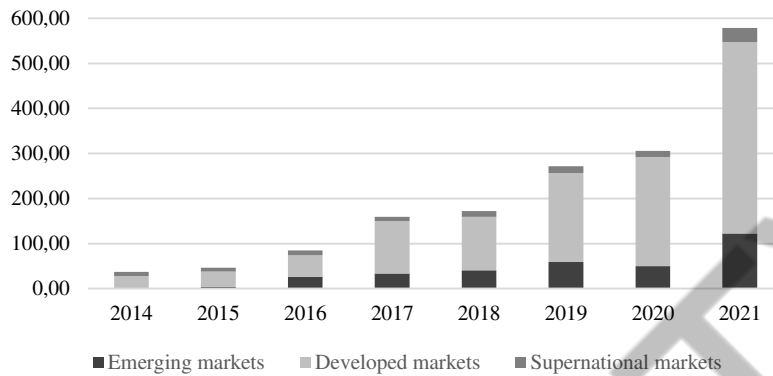


Fig. 1. The dynamics of the issue of "green" bonds in the world [2]

The total number of issuers increased by 32%, reaching 839 issuers. The average volume of individual "green" bonds increased by 51%, reaching the mark of \$250 million. This growth was facilitated by the addition of sovereign bonds from new and existing issuers [3]. In 2022, the "green" bond market continued to grow rapidly and exceeded the \$2 trillion mark at the end of September 2022 [4].

"Green" bonds are a powerful financial instrument that is rapidly developing in the context of climate change risks. In this context, the introduction of a climate-neutral economy by 2050 is recognized as a priority of the European Union [5].

## II. ANALYTIC OVERVIEW OF THE LITERATURE

The latest trends in economic demonstrate the concentration of scientists' attention on indicators of sustainable development. This is explained by the fact that in September 2015, within the framework of the 70th session of the UN General Assembly, the UN Summit on Sustainable Development was held in New York, the final document of which was 17 Goals of Sustainable Development and 169 objectives [6]. In this context, the issue of "green" bonds as a new powerful financing tool has become a topic that is widely discussed in the scientific community.

The dynamics of scientific publications in the field of "green" bond issuance over the past 5 years is shown in Fig.2, and their affiliation with countries – in Fig.3.

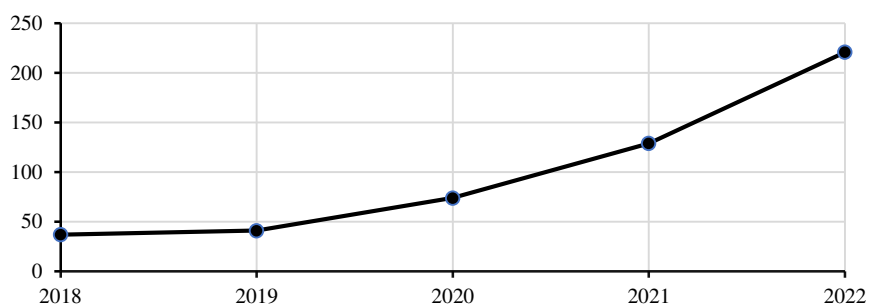


Fig. 2. Dynamics of scientific publications in the field of "green" bond issuance

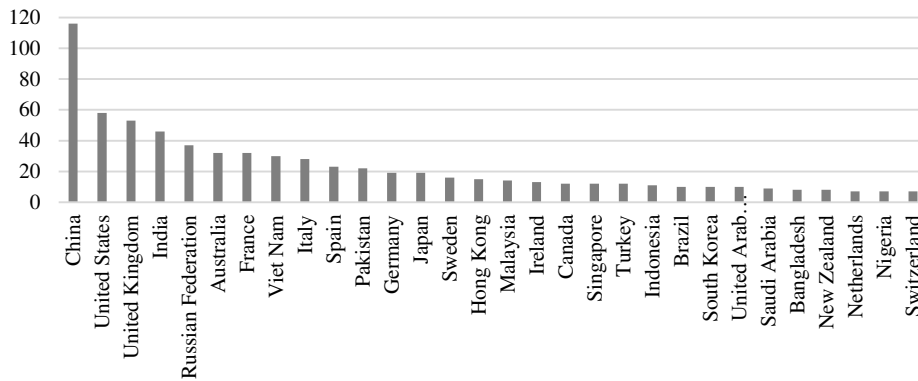


Fig. 3. Affiliation of scientific publications in the field of "green" bond issuance

The bibliometric analysis was carried out on the basis of a sample of 502 publications over the past 5 years, which was obtained from the Scopus database by the request TITLE-ABS-KEY("green bond\*"). The largest number of scientific publications over the past 5 years belongs to scientists from countries that have issued the largest number of "green" bonds. In the USA, "green" bonds were issued in the amount of \$334 billion, China - \$250 billion, France – \$189.7 billion, Great Britain - \$53.3 billion [2].

The level of development of the "green" bond market in different regions of the world varies. In many countries, "green" bonds are still not issued. Today, the European market occupies a leading position in terms of the volume of issuance of "green" bonds, followed by the markets of the Asia-Pacific region and North America.

Halkos in his work [7] measured the interdependence between 96 countries of the world using network analysis. He established that the USA and European countries play a leading role in the market of "green" bonds and are their main issuers in terms of frequency and volume. Dan and Tiron-Tudor in [8] investigated the determinants of the issuance of "green" bonds in the countries of the European Union in the period 2014-2019 and established that the countries of the European Union with a larger volume of issuance of "green" bonds are characterized, first of all, by high credit ratings, which increase the confidence of investors, and a large number of the population, which forms the demand for investment projects, the implementation of which involves attracting significant financial resources. ESG (Environmental, Social and Governance) risk rating and inflation rate also affect the volume of green bond issuance. Despite the existing scientific publications, it could be stated that insufficient attention is paid to the study of socio-economic determinants of the emission of "green" bonds in the world, especially during the period of rapid growth of their volume.

### III. OBJECT, SUBJECT AND RESEARCH METHODS

The object of the study is the "green" bond market. The subject of the study are socio-economic determinants of "green" bond issuance. With the aim of examining the relationship between the volume of "green" bond issuance in the world in 2021, when its jump-like growth took place, and the factors that characterize the environmental, social, governance and macroeconomic spheres of the countries, 7 independent variables were used. There are environmental, social, and governance risk index

(ESG), credit rating, trade openness, unemployment rate, inflation, GDP per capita, population. Correlation and regression analysis was used to determine the cause-and-effect relationship between variables, as well as the variables that have the greatest impact on the volume of "green" bond issuance.

#### IV. RESULTS OF THE WORK

##### 4.1. Database description and variables

To determine the socio-economic determinants of the emission of "green" bonds in the world in 2021, a linear regression model, which is based on previous studies [8] was built. As a dependent variable (*bonds\_value*), the amount of funds in US dollars raised through the issuance of "green" bonds in each of the 54 studied countries in 2021 was taken. The data were obtained from the Climate Bond Initiative database [2]. The independent variables were selected based on the analysis of scientific publications in the field of "green" bond issuance and are detailed in Table 1.

Tab. 1. Independent variables of the regression model

Independent variable	Variable description	Data source
<i>ESG_risk</i>	Environmental, social and governance (ESG) risk rating of the issuer's country of residence	[9]
<i>credit_rating</i>	Credit rating of the issuer's country of residence (ordinal scale)	[10]
<i>trade_openness</i>	Trade openness, measured as the level of exports of goods and services (% of GDP)	[11]
<i>unemployment_rate</i>	Unemployment rate in the issuer's country of residence, %	[11]
<i>inflation</i>	Consumer price index (CPI, 2010=100%)	[12]
<i>GDP_per_capita</i>	GDP of the issuer's country of residence per capita at purchasing power parity in international dollars	[11]
<i>population</i>	Population in the country, persons	[11]

*Environmental, Social, and Governance risk index (ESG)*. By now, investors move their attention to more soft aspects like environmental, social, and governance performance indicators when they decide to invest. ESG criteria are closely related to corporate social responsibility and socially responsible investment objectives [13]. The empirical studies reveal that the ESG indicators positively affect the bond market because of lower borrowing costs [14-17]. Other researchers analyzed the impact of ESG on the interest cost in the Chinese "green" bonds market and showed that a higher ESG score led to lower yield spreads, a better financial condition, and a long-term orientation [18]. Additionally, the extra financial performance has important economic roles at the country level. This supposed that countries have a long-term orientation, collaborate, and communicate with outside parties, leading to an increase in investor's trust. Besides, act as a buffer against adverse shocks, which is perceived as an extra guard against possible losses. ESG risk index provided by CountryRisk.io explains

how its components will affect the long-term sustainability of a country. If the risk is higher, there is a more increased need for financing.

*Rating.* Credit rating agencies are an independent organization that analyzes an issuer's creditworthiness using various information. It is well known that credit ratings have a significant influence on the bond market. The issuer's credit rating impacts the investment decision in green bonds, and the issuer can attract more investors if they have good ratings [19]. This fact leads by default to a large amount of "green" bond issues. Chiesa and Barua revealed the positive influence of rating on the issue amount [20]. Low ratings are associated with higher financing costs since it presents the issuer's ability to repay their debt and access capital market. A consequence of a low credit rating is a high cost of funding, as it demonstrates the ability of the issuer to repay its debt and access the capital market [21]. The sovereign rating provided by Fitch was used and converted into ordinal scale from 0 (DD) to 21 (AAA) following [22].

*Trade openness.* Trade openness represents the connection with the rest of the world. Tolliver found that trade openness led to the growth of the green bond market [23]. Previous studies also demonstrate that trade openness has an impact on financing costs. The prominence of this macroeconomic indicator increased after the financial crisis, when the researcher findings had revealed that a higher level of trade openness leads to lower bond spread.

*Inflation rate.* In the literature, the inflation rate is perceived as the quality of economic management that directly influences the default risks. Nickel stated that higher inflation rates lead to macroeconomic instability that lowers the government's creditworthiness [24]. Also, the inflation rate plays an essential role in accessing long-term finance by new EU countries [25]. Furthermore, Presbitero found that higher inflation leads to a lower probability of issuing government bonds, and the issuances will have a higher borrowing cost [26]. The inflation rate is a financial factor that influences the green market expansion, a higher level of inflation negatively affects the investor's decisions [27]. In addition, analyzing the OECD members Tu and Rasoulinezhad found that inflation has a negative and significant impact on energy efficiency [28]. Therefore, investors consider inflation when they decided to finance energy efficiency projects.

*Unemployment rate.* The development of the green bond market is also linked with social factors like the unemployment rate. So, using the analytic hierarchy process, Anh Tu found that expert's judgments consider the unemployment rate as a factor of influence of the issuance of green bonds [27]. The literature reveals that higher unemployment rates lead to an increase in the debt level obtained with higher costs [29].

*Gross domestic product per capita (GDP\_per\_capita).* The capacity to issue green bonds is positively influenced by the economy's size [23]. Analyzing the drivers of issuance of sovereign bonds in developing countries, Presbitero found that economic size, and higher per capita GDP characterize countries that frequently issue bonds [26]. Also, Glomsrød and Wei also found that when green financing increases, the GDP levels increase worldwide. The level of growth is more pronounced in the European Union [30].

*Population.* A large population constitutes an increasing demand for investment projects, which implies considerable financial resources. Green bonds can be used to attract money from investors to finance environmentally friendly projects. However, in countries with low population density, the green projects have a small size [31]. The country size is measure by the population number. Presbitero found that the population positively influences the issue of government bonds [26].

**4.2. Summary statistics and statistical analysis of data**

The software used for the model building was Stata 17. A statistical description of the independent variables of the model is presented in Fig.4.

Variable	Obs	Mean	Std. dev.	Min	Max
bonds_value	54	9.88e+09	1.88e+10	7000000	9.00e+10
ESG_risk	54	28.65444	14.72719	3.92	73.1
credit_rating	54	15.25926	4.622281	4	21
trade_openness	54	51.03961	38.39947	9.981151	212.1172
unemployment	54	6.582407	4.169369	.07	27.48
inflation	54	136.2247	40.41135	100	314.81
GDP_per_capita	54	43680.97	27635.29	5877.64	134753.8
population	54	1.00e+08	2.67e+08	287708	1.41e+09

Fig. 4. Descriptive statistics of the independent variables of the model

The average volume of "green" bond issuance is \$9.88 billion, with a range of \$0.007 to \$90 billion.

Significant discrepancies were found in the rating assessment of ESG risk. Switzerland, Germany, Norway, Sweden, and Denmark have the lowest values of this assessment. The highest are Pakistan, Argentina, Greece, and Brazil.

Argentina, Pakistan, and Ukraine have the lowest values of the credit rating assessment. The highest are Australia, Denmark, Germany, Norway, USA, Switzerland, Sweden. The average value of this grade is very high and equals 15 (A-).

Trade openness (export of goods and services as a percentage of GDP) averages 51%. There is a considerable variation between countries. Singapore has 185% while Pakistan has only 10%.

The highest levels of GDP per capita at purchasing power parity were registered in Luxembourg, Singapore, and Ireland. The lowest are in Pakistan and India.

Then we check the normality of the distribution of model variables using the Jacque-Bera and Shapiro-Wilk tests. The results are shown in Table 2. The proposed null hypothesis states that the corresponding variable has a normal distribution form. Variables for which the null hypothesis cannot be rejected are highlighted in bold.

Tab. 2. Testing for the normality of the distribution of the model variables

Independent variable	Jacque-Bera test		Shapiro-Wilk test		Is the shape of the distribution normal?
	$\chi^2$	$p$ -value	$W$	$p$ -value	
<i>bonds_value</i>	203,500	0	0,5644	0	No
<i>ESG_risk</i>	<b>2,385</b>	<b>0,3034</b>	<b>0,9652</b>	<b>0,1178</b>	Yes
<i>trade_openness</i>	143,300	0	0,7645	0	No
<i>credit_rating</i>	<b>3,070</b>	<b>0,2155</b>	<b>0,9645</b>	<b>0,1092</b>	Yes
<i>unemployment_rate</i>	270,5	0	0,8096	0	No
<i>inflation</i>	250,00	0	0,6493	0	No
<i>GDP_per_capita</i>	16,220	0,0003	0,9165	0,0011	No
<i>population</i>	963,200	0	0,3628	0	No

There are few examples of testing for the normality of the distribution of the independent variables described below.

Dependent variable "*bonds\_value*" was tested for normality with both the Jarque-Bera and Shapiro-Wilk tests. Both tests yielding  $p$ -values very close to 0 so we reject the null hypothesis that the variable is normally distributed (for  $\alpha=0.05$ ). Histogram of the distribution is presented in Fig. 5.

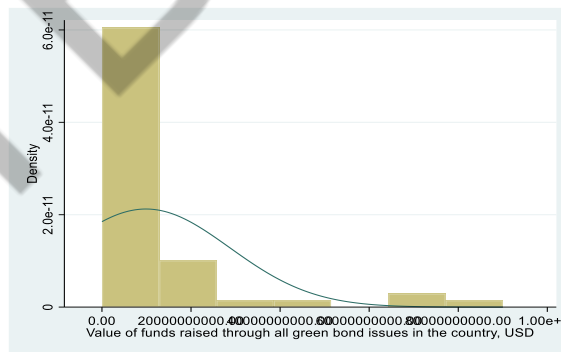


Fig. 5. Distribution of the dependent variable "*bonds\_value*"

Independent variable "*ESG\_risk*" was tested for normality with both the Jarque-Bera and Shapiro-Wilk tests. Both tests yielding  $p$ -values greater than 0.1 so we accept the null hypothesis that the variable is normally distributed (for  $\alpha=0.1$ ). Histogram of the distribution is presented in Fig. 6.

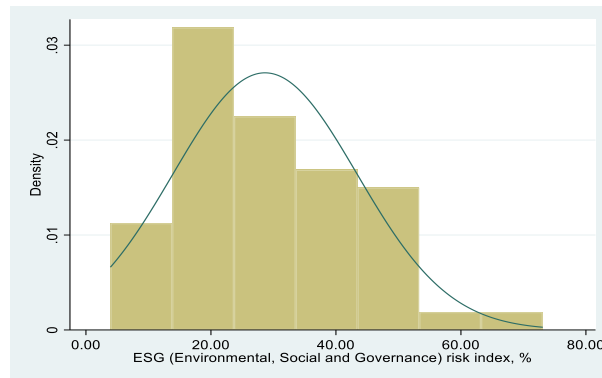


Fig. 6. Distribution of the independent variable "ESG\_risk"

In the next step, the correlation between the independent variables and the dependent variable of the model was analyzed. Considering the results of the preliminary test for the normality of the distribution of the model variables, Spearman's rank correlation coefficient was used as a measure of correlation. The results of the test are shown in Table 3. Variables with a weak correlation with the dependent variable are highlighted in bold. They were excluded from further consideration.

Tab. 3. Testing for correlation of the independent variables

Independent variable	Spearman's rank correlation coefficient		Is there a correlation?
	value	Prob >  t	
<i>ESG_risk</i>	-0,5263	0	Yes
<b><i>trade_openness</i></b>	<b>-0,1118</b>	<b>0,4207</b>	<b>No</b>
<i>credit_rating</i>	0,6251	0	Yes
<b><i>unemployment_rate</i></b>	<b>-0,1235</b>	<b>0,3738</b>	<b>No</b>
<i>inflation</i>	-0,4014	0,0026	Yes
<i>GDP_per_capita</i>	0,5289	0,0000	Yes
<i>population</i>	0,2486	0,0699	Yes

Note that according to the Chaddock scale, the values of the correlation coefficients have the following interpretation: 0.1÷0.3 – weak correlation; 0.3÷0.5 – moderate correlation; 0.5÷0.7 – noticeable correlation; 0.7÷0.9 – high correlation; 0.9÷1.0 – strong correlation.

#### 4.3. Selecting a functional form

Box-Cox transformation is used to determine whether and which variables in the model should be logarithmically transformed. So, this transformation [32] was applied to the model variables for which the hypothesis of a normal form of distribution was not confirmed, to determine the type of their transformation. The results are shown in Table 4. Hence, variables "*bonds\_value*", "*GDP\_per\_capita*", "*population*" should be logarithmically transformed.

Tab. 4. P-value of the Box-Cox transformation coefficient

Independent variable	Prob > $\chi^2$			Type of transformation
	$H_0: \lambda = -1$	$H_0: \lambda = 0$	$H_0: \lambda = 1$	
<i>bonds_value</i>	0,000	0,365	0,000	natural logarithm
<i>inflation</i>	0,000	0,000	0,000	—
<i>GDP_per_capita</i>	0,000	0,092	0,000	natural logarithm
<i>population</i>	0,000	0,931	0,000	natural logarithm

After the logarithmic transformation of the variables "*bonds\_value*", "*GDP\_per\_capita*", "*population*", the parameters of the regression model were estimated by the method of ordinary least squares (Fig. 5).

Source	SS	df	MS	Number of obs	=	54
Model	148.342983	5	29.6685966	F(5, 48)	=	20.67
Residual	68.9114925	48	1.43565609	Prob > F	=	0.0000
				R-squared	=	0.6828
				Adj R-squared	=	0.6498
				Root MSE	=	1.1982
Total	217.254475	53	4.09914104			

log_bonds_value	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
ESG_risk	.0345647	.0317881	1.09	0.282	-.0293496	.098479
credit_rating	.2408198	.1044389	2.31	0.025	.0308314	.4508083
inflation	.0030087	.0051909	0.58	0.565	-.0074283	.0134456
log_GDP_per_capita	1.641235	.4889218	3.36	0.002	.6581915	2.624278
log_population	.7758041	.1156618	6.71	0.000	.5432505	1.008358
_cons	-13.90836	6.510222	-2.14	0.038	-26.99804	-.8186845

Fig. 5. Estimated parameters of the constructed regression model

As it turned out, the variables "*ESG\_risk*" and "*inflation*" have a *p*-value above the acceptable level of 0.05 and were excluded from further consideration.

#### 4.4. Regression

The final regression equation with significant variables was obtained (Fig. 6).

Source	SS	df	MS	Number of obs	=	54
Model	146.31857	3	48.7728566	F(3, 50)	=	34.38
Residual	70.9359054	50	1.41871811	Prob > F	=	0.0000
				R-squared	=	0.6735
				Adj R-squared	=	0.6539
				Root MSE	=	1.1911
Total	217.254475	53	4.09914104			

log_bonds_value	Coefficient	Std. err.	t	P> t	[95% conf. interval]	
credit_rating	.1435692	.0632188	2.27	0.027	.0165905	.270548
log_GDP_per_capita	1.492665	.4689865	3.18	0.003	.5506781	2.434652
log_population	.7974753	.1126111	7.08	0.000	.5712892	1.023661
_cons	-9.834311	5.478962	-1.79	0.079	-20.83913	1.170509

Fig. 6. Estimated parameters of the final regression model

#### 4.5. Potential problems with the data

The verification of the presence of collinearity between individual variables in the model, which could negatively affect the interpretation of the results, was carried out using the variance inflation factor (VIF). The critical value of VIF is usually taken as 5. The results of the test are shown in Table 5.

Tab. 5. Testing for multicollinearity

Independent variable	VIF
<i>credit_rating</i>	3,19
<i>log_GDP_per_capita</i>	4,06
<i>log_population</i>	1,52

Since the calculated VIF value is relatively low, it can be concluded that multicollinearity is absent in the constructed model.

#### 4.6. Diagnostic tests

To check the accuracy and validity of the functional form of the model and to determine whether some of the key assumptions behind the properties of the OLS estimator are satisfied, the diagnostic tests were used.

##### *The RESET Test*

Since the available data sample is quite small, the Ramsey RESET test was used to test the functional form of the model only with the degrees of individual regressors, which confirmed the acceptability of the functional form of our model. The result of conducting Ramsey RESET Test is presented in Fig. 7.

```
Ramsey RESET test for omitted variables
Omitted: Powers of independent variables

H0: Model has no omitted variables

F(9, 41) = 0.73
Prob > F = 0.6775
```

Fig. 7. RESET Test output

##### *The Breusch-Pagan and The White Tests*

It should be noted that homoscedasticity is an important assumption, based on which the estimation of model parameters by the method of least squares is proved to be the best linear unbiased estimate (BLUE, Best Linear Unbiased Estimate). In the presence of heteroscedastic disturbances, this parameterization method may lose its effectiveness.

Testing for heteroskedasticity was performed using the Breusch-Pagan and White tests. Both tests confirmed the hypothesis of homoscedasticity of model residuals.

The Breusch-Pagan test yielded a  $p$ -value of 0.1306, which means that the null hypothesis cannot be rejected for  $\alpha=0.05$  or even  $\alpha=0.1$ .

The White test yielded a  $p$ -value of 0.2334, which means that the null hypothesis cannot be rejected for  $\alpha =0.05$  or even  $\alpha =0.1$ .

*Analysis of Residuals*

To analyze the residuals (versus normal distribution), the histogram was built (Fig.7). The shape of the distribution of residuals responds to normal distribution.

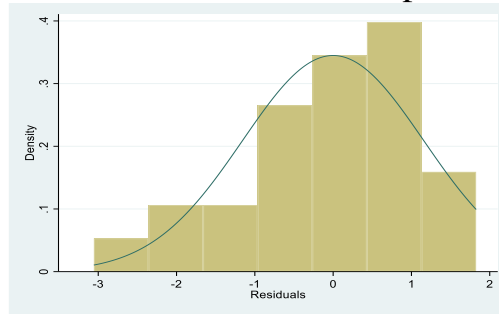


Fig. 7. The histogram of residuals

*Jarque-Bera Test*

To check the model residuals for the normality of the distribution, the Jarque-Bera test was conducted, which confirmed the hypothesis of the normality of the distribution of the model residuals. The resultant *p*-value of 0,1377 indicates that for  $\alpha=0.05$  or even  $\alpha=0.1$  the null hypothesis asserting normality cannot be rejected. It should be noted that the Jarque-Bera test often rejects this hypothesis for large data samples, detecting even minor deviations from a normal distribution.

The constructed regression equation has the form:

$$\log\_bonds\_value = -9.8343 + 0.1436credit\_rating + 1.5\log\_GDP\_per\_capita + 0,8\log\_population$$

- log\_bonds\_value* – logarithm of the volume of "green" bond issuance;
- credit\_rating* – rating assessment of the creditworthiness of the issuer's country of residence on an ordinal scale;
- log\_GDP\_per\_capita* – the logarithm of the GDP of the issuer's country of residence per capita at purchasing power parity;
- log\_population* – the logarithm of the country's population.

The estimated regression parameters indicate that a one-unit increase in the credit rating of the issuer's country of residence in the ordinal scale leads to a 14.36% increase in the volume of "green" bond issuance. A 1% increase in GDP per capita leads to a 1.5% increase in the volume of green bond issuance. A 1% increase in the total number of the country's population, in turn, leads to an increase in the volume of issuance of "green" bonds by 0.8%.

**V. CONCLUSIONS**

The obtained results showed that the rating assessment of the creditworthiness of the issuer's country of residence significantly affects the market of "green" bonds. Green bonds are a new financial instrument, and it is difficult for investors to assess the potential risks, so they rely on ratings. Investors use the credit rating as a tool for

assessing the issuer's default risk. To gain access to the financial market for financing environmentally friendly projects, the issuer needs a good rating. Therefore, the state should encourage issuers to receive ratings (bond rating, issuer rating, etc.). This will increase the demand for "green" bonds, which investors would perceive as a safe financial instrument.

According to the built model, the increase in the population has a positive effect on the level of emission of "green" bonds. This is consistent with the findings of [29], where the volume of bond issuance also increases with the population. This result can be explained by the fact that ecologically clean projects improve the quality of life of the population, and the growth of the population requires reliable and affordable "green" financing for ecologically clean projects.

Our research confirmed that the economic development of the country, characterized by GDP per capita, and the development of the "green" bond market go hand in hand.

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