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Article

Carbon Emissions and Stock Returns: The Case of Russia

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Abstract: Russia is taking the first steps in the formation of an emissions trading system. In this article, we studied the impact of carbon risk on Russian stock returns. We link carbon risk to CO_2 emissions and air protection costs. We suggest that carbon firms are exposed to carbon risk and hence require a premium in stock returns. We use an approach based on the asset pricing methodology for carbon, carbon-free, and "carbon-minus-carbon-free" portfolios. Based on the Newey–West estimate, we perform a linear regression analysis for the period from January 2014 to December 2021. We find a positive and statistically significant carbon premium. This means that carbon firms show higher expected returns. Carbon risk does not have a statistically significant impact on the carbon premium. The carbon firms' stock returns are not sensitive to CO_2 emissions and air protection costs. Our analysis shows that a quarter of the carbon premium is explained by the market premium and is not sensitive to size, value, and momentum premiums. Our results inform policymakers and investors about the implications of environmental regulation. Policymakers should take into account the results obtained in the development of national climate and, in general, environmental policies.

Keywords: carbon risk; stock returns; emissions trading system; climate policies

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1. Introduction

Russia faces the issue of forming a national climate agenda and, in general, environmental policy. The first trading in carbon units occurred at the National Commodity Exchange (part of the Moscow Exchange Group) in September 2022. Demand for carbon units is one of the factors for the successful development of trade. Demand comes from carbon firms that pollute the air with greenhouse gas emissions in the course of their production activities. We are interested in the question: do CO_2 emissions and air protection costs affect the market value (profitability) of carbon firms' shares? In other words, are carbon firms currently a potential source of demand for carbon units in Russian conditions?

"Carbon-free" firms generate positive externalities for society, and "carbon" firms impose negative externalities. Investing in green assets, also known as sustainable investing or responsible investing, has become extremely popular in recent years. According to the Global Sustainable Investment Review (GSIA 2020), there is a continuing prevalence of sustainable investment across the global investment industry, with assets under management reaching USD 35.3 trillion, a growth of 15% in two years, and in total equating to 36% of all professionally managed assets across regions covered in the report.

The current body of literature suggests that green assets may differ in return. Commonly, when bonds are taken under consideration, studies find significant carbon premiums: green bonds are less profitable compared to conventional bonds. However, the picture is not that clear when stocks are investigated. The empirical literature shows that green stocks often demonstrate the same returns that carbon stocks do. In some cases, the return on green stocks may be higher.

Asset pricing theory has always been a hot issue in finance research. One of the main questions of asset pricing theory is what returns are needed to compensate for a certain risk. In addition, the theory of finance substantiates that the strategic goal of a company is to maximize its market value, which depends on the market price (and hence returns) of the company's shares. Therefore, the question about factors that determine stock returns is a research interest. Different models of pricing securities and thereby determining expected returns on capital investments have been improved and developed over the years. CAPM was the first. The CAPM was introduced by Jack Treynor, William F. Sharpe, John Lintner, and Jan Mossin independently. CAPM has argued the relationship between the expected rate of return of assets in the securities market and risky assets and occupies a dominant position in modern finance. CAPM considered the market premium as a factor only. CAPM was established on a series of strict assumptions. In particular, CAPM is based on the efficient market hypothesis (EMH). If the market is efficient, then it is impossible for the investors to achieve an abnormal rate of return or "alpha". Additional return is provided only at the expense of additional risk. CAPM single factor model performs poorly in many empirical studies (such as dealing with the market value effect, explaining the excess return of assets, etc.). Since then, many scholars have tried to obtain new models by weakening the constraints of CAPM or adding new factors. The most famous of which is the FF three-factor model. In 1993, Fama and French (Fama and French 1993) came up with the three-factor model, with its two additional factors being size and value on the basis of CAPM. The three-factor model was a significant improvement over the CAPM. But, the FF three-factor model cannot explain financial anomalies such as momentum effects. Carhart (Carhart 1997), on the basis of the FF three-factor model, constructed the momentum factor and obtained the four-factor model. After empirical analysis, it is concluded that the four-factor model, compared with the three-factor model, can better evaluate portfolio returns. In general, empirical studies show that the factor model cannot fully take into account various possible influencing factors in real market conditions. Therefore, current studies of asset pricing factor models are mainly focused on the construction of new impact factors (Ren 2022).

Carbon firms emitting carbon are exposed to carbon risk and therefore require a higher expected return compared with carbon-free firms. We associate carbon risk with CO_2 emissions and the air protection cost, which can affect a firm's financial performance. It is important to note that there is currently considerable uncertainty regarding various aspects of the national climate agenda implementation. We justify a new risk for Russian companies: the carbon risk, by which we mean the uncertain possibility of charging polluters for air pollution, which depends on the amount of CO_2 emissions. The impact of spending (state and business) on environmental protection measures on Russian companies' share returns is also the focus of our attention. They are associated with uncertainty about the economic effectiveness of climate projects. In this article, we take this factor's approach as a basis in order to investigate the impact of CO_2 emissions and the atmospheric air protection cost on the Russian companies' share returns.

Foreign scientists have studied the impact of carbon regulation on the financial performance of firms. We will cite key publications in this area of research. When discussing if carbon emissions are associated with stock returns or firm fundamentals, questions about risks and investors' behavior arise. Bolton and Kacperczyk (2021) found that stocks of U.S. firms with higher total CO_2 emissions (and changes in emissions) earn higher returns but could not explain this carbon premium through differences in unexpected profitability or other known risk factors. They also revealed that institutional investors are already demanding compensation for their exposure to carbon emission risk.

As noted by Aswani et al. (2023), carbon-related risk potentially arises from future cash flow shocks resulting from both direct actions (e.g., carbon taxes or remedial environmental costs that the emitter might be forced to incur on behalf of the taxpayer) as well as indirect actions (e.g., changing consumer taste functions). Also, investors themselves may be concerned about how "green" the company they own is.

The authors discussed investors' preference stories. Standard asset pricing models assume that investors choose asset holdings based solely on anticipated payoffs. Fama and French (2007) provide a simple framework for studying how assets as consumption goods can affect asset prices. If investors have tastes for green assets and these tastes do not depend on firms' performance, then they will change their demand from assets that are less green to assets that are greener. Ceteris paribus, in these circumstances, green assets have to be priced more than carbon assets and therefore have less return.

The authors concluded that the risk is the reason why carbon emissions may affect stock returns. Emissions may be linked to financial performance, and thus, carbon emissions may be viewed as a source of risk for which investors seek compensation. Such compensation would manifest as a risk premium, observable as a positive relation between emissions and stock returns: the greener a company is, the lower the return of its stocks.

Baker et al. (2018) constructed a model of economic equilibrium that contains two types of investors: the first type is oriented to getting high returns under the given level of risk, and the second type has tastes for green assets. According to the model, green assets should have lower expected returns and more concentrated ownership. The authors supported their prediction when investigating the bonds market: green bonds demonstrate lower returns.

Pastor et al. (2021) showed that in equilibrium, green assets have low expected returns because investors enjoy holding them and because green assets hedge climate risk. However, green assets may outperform when positive shocks hit the ESG factor, which captures shifts in customers' tastes for green products and investors' tastes for green holdings.

Löffler et al. (2021) found that green bonds have larger issue sizes and lower-rated issuers, on average, compared to conventional bonds. The estimates showed that the yield for green bonds is, on average, 15–20 basis points lower than that of conventional bonds, both on primary and secondary markets.

Pastor et al. (2022) demonstrated that green assets delivered high returns in recent years, and this performance reflected unexpectedly strong increases in environmental concerns, not high expected returns.

Madhavan et al. (2021) investigated U.S. mutual funds in terms of their returns and ESG rating. The authors stated that funds with high environmental scores tend to have high quality and momentum factor loadings. In their opinion, high sensitivity to momentum can be interpreted as an increase in environmental concerns.

Oestreich and Tsiakas (2015) stated that German firms that received free carbon emission allowances, on average, significantly outperformed firms that did not. However, this effect can be seen during the first few years (from January 2005 to December 2007) of the European Union's Emissions Trading Scheme. When the authors used an extended study period (from January 2003 to December 2012), the return of the dirty-minus-clean portfolio became statistically insignificant.

Some authors investigated emerging markets instead of being concentrated only in developed markets. Sherwood and Pollard (2017) measured the performance indicators (Sharpe ratio, Sortino ratio) of investing in MSCI Emerging Markets indices. The authors then evaluated the same performance metrics for the MSCI Emerging Markets ESG Indices, which include only high ESG-rated stocks rated by MSCI. The authors showed that investing in MSCI Emerging Markets ESG Indices had a higher level of efficiency.

Little attention is paid to the performance of sustainable investing in the Russian stock market. Ovechkin et al. (2021) investigated if the return of momentum strategy in the Russian stock market can be improved by using ESG rating when calculating momentum. The authors showed that the momentum-ESG strategy has a higher Sharpe ratio relative to the standard momentum strategy. Ovechkin and Boldyreva (2022) examined if the return of Russian stocks with high ESG ratings differs from the return of stocks with low ESG ratings. The authors measured responsibility premium, which is defined as the return of high ESG-rated stocks minus the return of low ESG-rated stocks. The authors found that responsibility premium is insignificant: stocks with high ESG rating gain as much return as stocks with low ESG ratings do.

Thus, when investigating green bonds, the common result is that the return of green bonds is lower relative to the return of conventional bonds. However, the picture is not so clear when stocks are taken under consideration. Very often, researchers conclude that the return of the green stock may be least at the same level as the carbon stocks return. This paper fills the gap in the literature by providing a comprehensive empirical investigation of the effect of carbon risk on stock returns. We assess the presence of a carbon premium in the Russian stock market.

In this study, we seek to investigate if there is a significant difference between returns of carbon and carbon-free Russian stocks and how these returns can be explained by premiums and changes in carbon emissions and air protection costs. These research issues differ the article from the current literature. Thus, the following hypotheses are made:

H1. *The carbon portfolio return is significantly higher than the carbon-free portfolio return. In other words, we estimate if there is a carbon premium in the Russian stock market.*

H2. *The carbon premium, as the difference between the carbon portfolio return and the carbon-freer portfolio return, is sensitive to changes in*CO_2 *emissions and air protection costs.*

As was shown in the literature review, carbon premiums may be sensitive to other risk premiums (or factors). We are going to investigate if carbon premium may be explained by market premium, size premium, value premium (also referred to as high minus low (HML)), and momentum (fully or partly) in the Russian stock market.

H3. *The "carbon-minus-carbon-free" portfolio return (or the carbon premium) is sensitive to risk premiums (market premium, size premium, value premium, and momentum).*

The rest of the paper is organized as follows. In Section 2, we substantiate and describe the analysis methodology and data. In Section 3, we discuss the results of the analysis. In Section 4, we draw our main conclusions and formulate directions for future research.

2. Materials and Methods

We conduct econometric analysis to answer the main question of our study: whether there is a carbon premium in stock returns. To answer this question, we used the approach of distinguishing three portfolios and defining the carbon premium as the "carbon-minus-carbon-free" portfolio return proposed by Oestreich and Tsiakas (2015). We form three portfolios: carbon, carbon-free and "carbon-minus-carbon-free". A carbon portfolio is a portfolio of firms emitting CO_2 and incurring air protection costs. A carbon-free portfolio is a portfolio of firms that do not emit CO_2 and do not bear the cost of protecting the atmospheric air. Building a "carbon-minus-carbon-free" portfolio is equivalent to going long the carbon portfolio and going short the carbon-free portfolio. The "carbon-minus-carbon-free" portfolio allows us to better understand the role of carbon emissions and air protection costs in shaping firms' financial performance.

We consider carbon emissions and air protection costs as criteria for distinguishing between carbon and carbon-free firms. We did not find firm-specific carbon emissions data or firm-specific air protection cost data. The Federal State Statistics Service of Russia (FSSS) provides CO_2 emissions data and air protection cost data by industry. Therefore, to answer the main question of the study, we used FSSS data to identify "carbon" industries and "carbon-free" industries in Russia. Sources of air pollutants emissions are divided into stationary and mobile. Emissions from stationary sources occupy the largest share of the total volume of pollutants (77.2% in 2021). According to FSSS, the largest emissions of pollutants into the atmosphere from stationary sources are associated with the extraction of minerals (oil and natural gas, coal, metals, etc.); manufacturing industries (primarily metallurgy, production of coke and petroleum products, chemicals and chemical products); supply of electricity, gas, and steam; air conditioning; etc. For econometric analysis, we assume that air protection costs and preventing climate change in Russia as a whole are borne only by carbon firms.

Our empirical analysis uses an extensive dataset of monthly Russian stock returns in the corresponding indices. We used the indices calculated by the Moscow Exchange to form the carbon and carbon-free portfolios. The carbon portfolio is made up of stocks included in five sectorial indices of the Moscow Exchange, which belong to the "carbon" industries: MOEX Chemicals Total Return Index (MECHTR) (includes 7 companies), MOEX Electric Utilities Total Return Index (MEEUTR) (includes 15 companies), MOEX Metals and Mining Total Return Index (MEMMTR) (includes 13 companies), MOEX Oil & Gas Total Return Index (MEOGTR) (includes 10 companies), MOEX Transportation Total Return Index (METNTR) (includes 6 companies). Each "carbon" industry has an equal weight in the carbon portfolio. The carbon-free portfolio consists of companies' shares included in three sectorial indices of the Moscow Exchange that do not belong to "carbon" industries: MOEX Consumer Total Return Index (MECNTR) (includes 14 firms), MOEX Financials Total Return Index (MEFNTR) (includes 11 firms), and MOEX Telecommunication Total Return Index (METLTR) (includes 4 firms). The carbon-free portfolio does not include stocks of companies from the MOEX IT Total Return Index (MEITTR) (includes 7 firms) and MOEX Construction Total Return Index (MERETR) (includes 4 firms) because these indices are calculated from 2021. The carbon-free portfolio also has an equally weighted structure. A "carbon-minus-carbon-free" portfolio is the difference between the returns of the respective portfolios. The sample period used in our analysis ranges from January 2014 to December 2021. The number of return observations was 95.

The market portfolio return is determined by the MOEX Broad Market Index (MOEXBMI) (includes 40 companies). Our proxy for the monthly risk-free rate is the MOEX Government Bond Index (RGBITR) (includes 23 issues of government bonds). The Fama–French size factor (Fama and French 1993) is calculated on the basis of the MOEX SMID Total Return Index (MESMTR) (includes 38 companies of small and medium capitalization) and the MOEX Blue Chip Total Return Index (MEBCTR) (includes 15 companies). The Fama–French HML factor (Fama and French 1993) based on book-to-market value ratios is calculated on the basis of the MOEX Broad Market Index (MOEXBMI). We divide stocks that the MOEXBMI includes into 4 equal weighted groups (quartiles). The HML factor is, therefore, the return of the first quartile (stocks with the highest book-to-market ratio) minus the return of the fourth quartile (stocks with the lowest book-to-market ratio).

In order to construct momentum (Carhart 1997), we divided stocks into 4 equal groups (quartiles). The first quartile contains stocks that show the highest return for the previous 12 months (the last month is not included). The fourth group contains shares that show the lowest return for the same time period. Momentum is the difference between the returns of stocks of the first group and the fourth. Monthly carbon emissions and monthly air protection costs are calculated by dividing the annual values by 12 months based on the assumption of their uniform distribution.

The stationarity of time series is an important condition for their analysis. We test time series for stationary using the Dickey–Fuller test (Dickey and Fuller 1979). Data series are used in the log-differenced form. In addition to the Dickey–Fuller test, we perform a KPSS test (Kwiatkowski et al. 1992). We examined the correlation between variables. Then, we used several OLS models with multiple stationary time series to reveal various relationships in the formation of Russian stock returns. For each of the generated portfolios (carbon, carbon-free, and "carbon-minus-carbon-free"), we designed three time-series regressions to investigate the effect of CO_2 emissions and air protection costs on the public companies' stock returns listed on the Moscow Exchange.

The first regression is based on the Capital Asset Pricing Model (CAPM), which is specified as the following equation:

$$r_t - r_{rf_t} = \alpha + \beta_M \cdot \text{Market}_t + \varepsilon_t, \quad (1)$$

where r_t is the monthly portfolio return at time t for being one of the carbon or carbon-free portfolios, r_{rf_t} is the monthly risk-free rate at time t, Market_t is the monthly market premium at time t, and ε_t is the error term.

The second regression is a 4-factor model (FM4):

$$r_t - r_{rf_t} = \alpha + \beta_M \cdot \text{Market}_t + \beta_S \cdot \text{Size}_t + \beta_{HML} \cdot \text{HML}_t + \beta_{Mom} \cdot \text{Momentum}_t + \varepsilon_t, \quad (2)$$

where Size_t is the monthly size premium at time t, HML_t is the monthly HML premium at time t, and Momentum_t is the monthly momentum premium at time t.

The third regression is a 6-factor model (FM6):

$$\begin{gathered} r_t - r_{rf_t} = \alpha + \beta_M \cdot \text{Market}_t + \beta_S \cdot \text{Size}_t + \beta_{HML} \cdot \text{HML}_t + \beta_{Mom} \cdot \text{Momentum}_t + \\ \beta_{CO2} \cdot CO2_t + \beta_{Cost} \cdot \text{Cost}_t + \varepsilon_t, \end{gathered} \quad (3)$$

where $CO2_t$ is the relative change in CO_2 emissions per month, and Cost_t is the relative change in cost per month.

The regression equations for the "carbon-minus-carbon-free" portfolio differ from Equations (1)–(3) in the left part, which is the difference between the carbon portfolio return and the carbon-free portfolio return.

We implement OLS regressions to show that there is a positive price of carbon risk since carbon firms exhibit higher expected returns and move to the alpha of these portfolios. We define the alpha of the "carbon-minus-carbon-free" portfolio as the carbon premium. This is the abnormal excess return of the carbon portfolio over the carbon-free portfolio. The size and significance of the carbon premium are the focus of our empirical analysis.

We tested the residuals of the regression equation, the parameters of which were estimated using OLS method, for the presence of autocorrelation (the Breusch–Godfrey LM test is applied, the correlogram of the residuals is analyzed), heteroscedasticity (the Breusch–Pagan–Godfrey test and the White test are used) and ARCH processes (the ARCH-LM test is used, the correlogram of squared residuals is analyzed). We also tested the residuals for a normal distribution. We tested the adequacy of the model specification using the Ramsey test (the RESET test). The absence of autocorrelation of the residuals and their homoscedasticity are the conditions for the adequacy of the linear regression model. In the case of the detection of autocorrelation and heteroscedasticity and in the absence of ARCH processes, we used robust standard errors in the Newey–West form (Newey and West 1987).

Several metrics are used to evaluate the quality of the model in this study. We use the standard error of regression (SE), the adjusted R-square, and the Akaike and Schwartz information criteria. SE allows you to compare models of the same type with a different number of observations and variables. The quality of the generated models is better if the standard error is lower and the adjusted R-square is higher. Information criteria, which are to be minimized, allow you to choose the best model from a variety of models (William 2011).

3. Results

The analytical part of the article begins with the study of descriptive statistics. The descriptive statistics of the data series are presented in Table 1.

Table 1. Descriptive statistics for data series.

	Number	Minimum	Maximum	Mean	Median	Standard Deviation	Skewness	Kurtosis
Carbon portfolio returns (Rc)	95	−0.096	0.164	0.015	0.018	0.041	−0.130	1.599
Carbon-free portfolio returns (Rcf)	95	−0.123	0.128	0.009	0.010	0.046	−0.126	0.647
"Carbon-minus-carbon-free" portfolio returns (Rc-cf)	95	−0.037	0.065	0.006	0.005	0.017	0.158	1.124
Market	95	−0.132	0.161	0.004	0.006	0.044	0.043	1.896
Size	95	−0.083	0.091	−0.001	−0.001	0.035	0.035	−0.041
HML	95	−0.271	0.245	−0.017	−0.006	0.119	−0.003	−0.283
Momentum	95	−0.207	0.132	0.015	0.018	0.047	−1.032	4.540
CO_2	95	−0.054	0.054	0.001	0.000	0.010	1.537	19.938
Cost	95	−0.090	0.383	0.006	0.000	0.045	6.750	51.475

Descriptive statistics show that, in general, the data are close to the normal distribution law. The distribution of CO_2 emissions and costs has a right-sided asymmetry and a large kurtosis.

Correlation analysis of portfolios returns and factors based on a matrix of paired correlation coefficients revealed the relationship of variables (Table 2).

Table 2. Correlation matrix of factors and carbon portfolio returns.

	Rc	**Rcf**	**Rc-cf**	**Market**	**Size**	**HML**	**Momentum**	**CO_2**	**Cost**
Rc	1								
Rcf	0.76	1							
Rc-cf	0.75	0.14	1						
Market	0.79	0.67	0.52	1					
Size	−0.09	−0.03	−0.11	−0.40	1				
HML	0.20	0.13	0.17	0.11	−0.02	1			
Momentum	−0.14	−0.24	0.04	−0.02	−0.09	−0.16	1		
CO_2	−0.14	−0.20	−0.01	0.02	0.00	0.08	0.17	1	
Cost	0.10	0.13	0.02	0.12	−0.21	0.06	0.01	0.25	1

An analysis of the matrix of paired correlation coefficients shows a strong correlation between the market premium and the carbon and carbon-free portfolio returns (0.79 and 0.67, respectively). The correlation between the market premium and the "carbon-minus-carbon-free" portfolio returns is at the level of 0.52. Correlation coefficients show a weak negative relationship between portfolio returns and growth in carbon emissions (from −0.20 to −0.01) and a weak positive relationship between portfolio returns and growth in air protection cost (from 0.02 to 0.13). There is quite a strong relationship between the carbon and the carbon-free and the "carbon-minus-carbon-free" portfolio returns (0.76 and 0.75, respectively).

The dynamics of the actual cumulative returns of the carbon, carbon-free, and "carbon-minus-carbon-free" portfolios are shown in Figure 1.

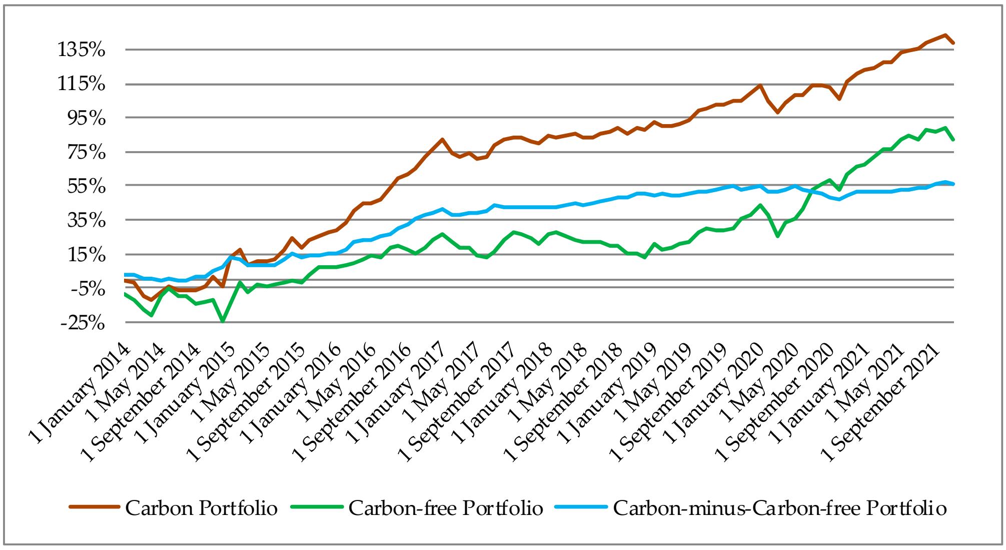

Figure 1. The actual cumulative returns of the carbon, carbon-free, and "carbon-minus-carbon-free" portfolios.

Visual analysis shows that the carbon portfolio cumulative return exceeds the carbon-free portfolio cumulative return. It should be noted that the cumulative carbon premium is increasing.

For correct modeling, it is necessary to ensure the stationarity of the time series. Results of the Dickey–Fuller test (Table 3) allow rejecting the null hypothesis that there is a unit root.

Table 3. Augmented Dickey–Fuller test for variable values.

	Rc	Rcf	Rc-cf	Market	Size	HML	Mom	CO_2	Cost
p-value with a constant	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
p-value with constant and trend	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Results of the KPSS test are presented in Table 4: LM-stat is below the critical value for every variable. Thus, we cannot reject the null hypothesis that a univariate time series is trend stationary.

Table 4. Kwiatkowski–Phillips–Schmidt–Shin test results (with constant).

	Rc	Rcf	Rc-cf	Market	Size	HML	Mom	CO_2	Cost
LM-Stat	0.09249	0.24965	0.3137	0.1223	0.3347	0.0634	0.2944	0.1564	0.2038
Asymptotic critical value (10% level)	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347

Table 5 presents the performance of the projected portfolios: mean, standard deviation, and Sharpe ratio. CAPM-α is the alpha of the CAPM regression, FM4-α is the alpha of the 4-factor regression, and FM6-α is the alpha of the 6-factor regression. The *p*-value (the *p*-value based on Newey and West (1987) standard errors) is shown in parentheses.

Table 5. The performance of designed portfolios.

	Mean	SDev	SR	CAPM-α	FM4-α	FM6-α
Carbon portfolio	0.015	0.041	0.205	0.005 (0.022)	0.004 (0.038)	0.005 (0.030)
Carbon-free portfolio	0.009	0.046	0.054	−0.001 (0.828)	0.000 (0.974)	0.000 (0.994)
Carbon-minus-carbon-free portfolio	0.006	0.017	−0.017	0.005 (0.001)	0.005 (0.007)	0.005 (0.007)

For the carbon portfolio, alpha is statistically significant at 5% in CAPM, FM6, and FM4. The alpha value is 6.2%, 4.9%, and 6.2% in annual terms for CAPM, FM4, and FM6, respectively. For a carbon-free portfolio, alpha is statistically insignificant for all regressions. The "carbon-minus-carbon-free" portfolio has a significant positive alpha of 1% for all regressions (the alpha value is 6.2% per annum). Thus, on the Russian stock market, the carbon premium is statistically significant at the level of 1%, and its value is 0.5% per month (6.2% per year), i.e., the carbon portfolio return is statistically significantly higher than the carbon-free portfolio return. Therefore, the H1 hypothesis cannot be rejected.

Table 6 reports beta and its significance for risk premiums, as well as changes in CO_2 emissions and air protection cost in the CAPM, FM4, and FM6 regression equations for the carbon portfolio.

In all regression equations, the carbon portfolio has a positive and statistically significant beta at the 1% level for the market and size premiums. The market premium and the size premium have a statistically significant effect on the excess carbon portfolio return (with the growth of these premiums, the carbon portfolio return increases). The HML beta is positive and statistically significant at the 10% level in the FM4 and FM6 equations. The momentum beta is positive and statistically significant at the 5% level in the FM4 and FM6 equations. Beta CO_2 factor and cost factor are not statistically significant; they do not affect the polluting firm's stock returns in Russian conditions. The market premium and the size premium have the biggest impact on stock returns. The value of the HML beta is small.

Table 6. Carbon portfolio regression coefficients and their significance.

Indicators	CAPM	FM4	FM6
Market	0.804	0.913	0.914
(*p*-value)	(0.000)	(0.000)	(0.000)
Size	-	0.364	0.363
(*p*-value)		(0.000)	(0.000)
HML	-	0.029	0.031
(*p*-value)		(0.092)	(0.074)
Momentum	-	0.089	0.096
(*p*-value)		(0.022)	(0.017)
CO_2	-	-	−0.157
(*p*-value)			(0.198)
Cost	-	-	−0.012
(*p*-value)			(0.612)

The dynamic of the actual and model cumulative returns of the carbon portfolio is shown in Figure 2.

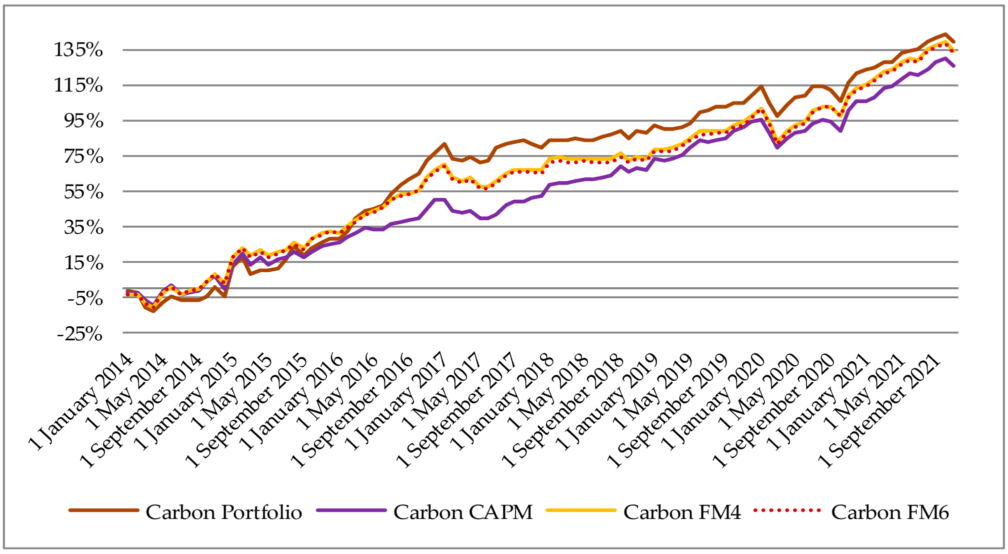

Figure 2. Actual and model cumulative returns of the carbon portfolio.

The dynamic of all model cumulative returns of the carbon portfolio repeats the dynamic of its real cumulative returns accurately. FM4 and FM6 model the behavior of the carbon portfolio cumulative returns more exactly. The FM4 and FM4 lines are visually inseparable, which indicates that the CO_2 and cost factors have no effect on the carbon portfolio returns almost.

Table 7 reports the quality of the regression equations for the carbon portfolio.

Table 7. Quality metrics for carbon portfolio regression equations.

Indicators	CAPM	FM4	FM6
Standard error	0.022	0.018	0.018
Adjusted R^2 (%)	72.72	81.12	80.91
p-value (F)	0.000	0.000	0.000
Akaike criterion	−455.35	−487.43	−484.54
Schwartz criterion	−450.24	−474.66	−466.66
Ramsey test (RESET) (squares), *p*-value	0.238	0.893	0.859
LM test, *p*-value	0.926	0.969	0.964
White's test, *p*-value	0.481	0.000	0.003
Breusch–Pagan test, *p*-value	0.864	0.028	0.091
ARCH processes test, *p*-value	0.360	0.660	0.704
Normal error distribution test, *p*-value	0.287	0.170	0.140

The FM4 and FM6 regression equations have the lowest standard error and the highest adjusted R^2. The Ramsey test shows the adequacy of the linear specification for all equations. There is no autocorrelation in the residuals of all regression equations for the carbon portfolio. ARCH processes are missing. Residuals have a normal distribution. In the presence of heteroscedasticity, estimates in the Newey–West form were used.

Table 8 reports beta and its significance for risk premiums, as well as changes in CO_2 emissions and air protection cost in the CAPM, FM4, and FM6 regression equations for the carbon-free portfolio.

Table 8. Carbon-free portfolio regression coefficients and their significance.

Indicators	CAPM	FM4	FM6
Market	0.765	0.890	0.890
(*p*-value)	(0.000)	(0.000)	(0.000)
Size	-	0.400	0.418
(*p*-value)		(0.000)	(0.000)
HML	-	0.004	0.007
(*p*-value)		(0.813)	(0.669)
Momentum	-	−0.037	−0.017
(*p*-value)		(0.695)	(0.846)
CO_2	-	-	−0.462
(*p*-value)			(0.019)
Cost	-	-	0.060
(*p*-value)			(0.044)

In all regression equations, the carbon-free portfolio has positive and statistically significant beta at the 1% level for the market premium and size premium, as in the case of the carbon portfolio. The value of the size premium beta is two times less than the market premium beta. The HML beta is statistically insignificant. The momentum beta is statistically insignificant for the carbon-free portfolio in the Russian stock market. In the FM6 equation, the beta of the CO_2 factor is negative and statistically significant at the 5% level; the value of beta is half of the market premium beta and is almost equal to the size premium beta by absolute value. The beta of the cost factor is positive and statistically significant at the level of 5%, but the value of the beta is more than 10 times less than the market premium beta. In general, the market premium has the most positive impact on the excess return of the carbon-free portfolio.

The dynamic of the actual and model cumulative returns of the carbon-free portfolio is shown in Figure 3.

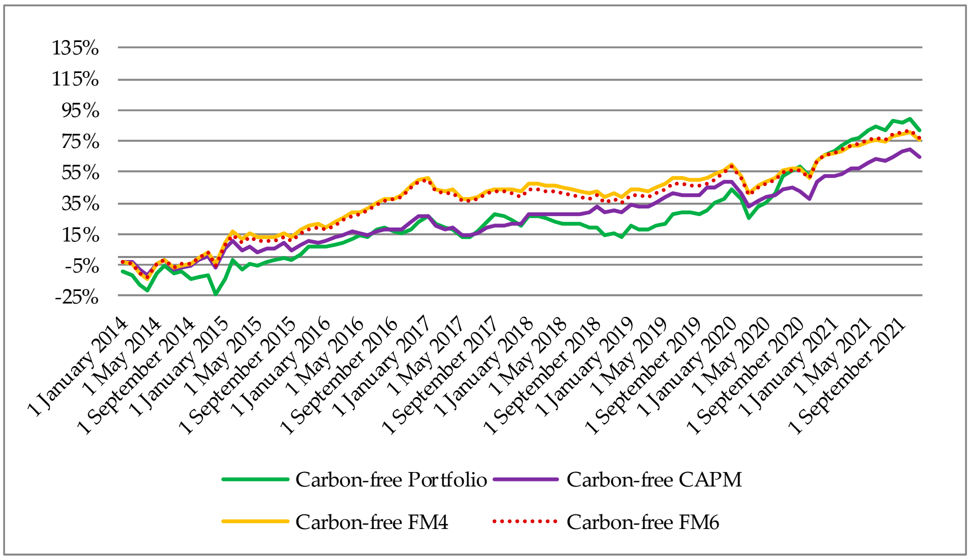

Figure 3. Actual and model cumulative returns of the carbon-free portfolio.

The dynamic of the model cumulative returns of the carbon-free portfolio FM4 and FM6 repeats the dynamics of its actual cumulative returns. The FM3 and FM5 lines are visually inseparable, which means that the CO_2 and cost factors have almost no effect on the carbon-free portfolio returns.

Table 9 reports the quality of regression equations for the carbon-free portfolio.

Table 9. Quality metrics for carbon-free portfolio regression equations.

Indicators	CAPM	FM4	FM6
Standard error	0.025	0.022	0.021
Adjusted R^2 (%)	64.60	73.77	74.55
p-value (F)	0.000	0.000	0.000
Akaike criterion	−428.91	−454.52	−455.51
Schwartz criterion	−423.80	−441.75	−437.63
Ramsey test (RESET) (squares), *p*-value	0.250	0.235	0.206
LM test, *p*-value	0.352	0.965	0.980
White's test, *p*-value	0.566	0.000	0.001
Breusch–Pagan test, *p*-value	0.290	0.022	0.009
ARCH processes test, *p*-value	0.513	0.446	0.320
Normal error distribution test, *p*-value	0.256	0.118	0.129

FM4 and FM6 equations are of high quality. The Ramsey test shows the adequacy of the linear specification for all equations. There is no autocorrelation in the residuals in all regression equations for the carbon-free portfolio. ARCH processes are missing. The residuals do not have a normal distribution. In the presence of heteroscedasticity, estimates in the Newey–West form were used.

Table 10 reports beta and its significance for risk premiums, as well as changes in CO_2 emissions and air protection cost, in the CAPM, FM4, and FM6 regression equations for the "carbon-minus-carbon-free" portfolio.

Table 10. "Carbon-minus-carbon-free" portfolio regression coefficients and their significance.

Indicators	CAPM	FM4	FM6
Market (*p*-value)	0.198 (0.000)	0.212 (0.000)	0.213 (0.000)
Size (*p*-value)	-	0.060 (0.256)	0.059 (0.270)
HML (*p*-value)	-	0.017 (0.178)	0.018 (0.166)
Momentum (*p*-value)	-	0.029 (0.468)	0.032 (0.445)
CO_2 (*p*-value)	-	-	−0.064 (0.116)
Cost (*p*-value)	-	-	−0.005 (0.497)

The "carbon-minus-carbon-free" portfolio has a positive statistically significant beta of the market premium only in all regression equations. The market premium explains one-fourth of the variation in the dependent variable. The other premiums considered (size, HML, momentum), as well as changes in CO_2 emissions and air protection cost, do not affect the carbon premium.

The dynamic of the actual and model cumulative returns of the "carbon-minus-carbon-free" portfolio is shown in Figure 4.

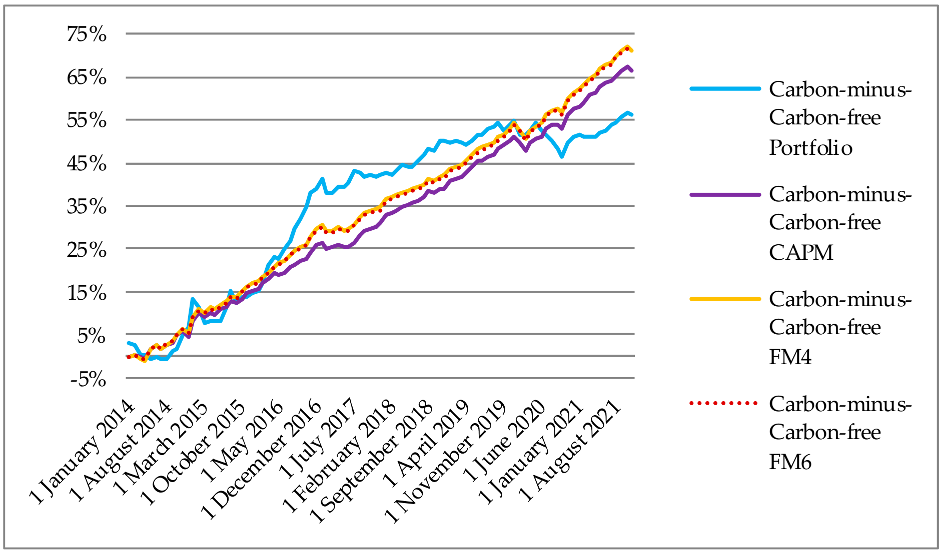

Figure 4. Actual and model cumulative returns of the "carbon-minus-carbon-free" portfolio.

The dynamic of all model cumulative returns of the "carbon-minus-carbon-free" portfolio repeats the dynamics of its real cumulative returns. The FM4 and FM6 lines are visually inseparable. It indicates that the CO_2 and cost factors have almost no effect on the "carbon-minus-carbon-free" portfolio returns.

Table 11 reports the quality of regression equations for the "carbon-minus-carbon-free" portfolio.

Table 11. Quality metrics for "carbon-minus-carbon-free" portfolio regression equations.

Indicators	CAPM	FM4	FM6
Standard error	0.015	0.014	0.015
Adjusted R^2 (%)	26.19	26.87	25.41
p-value (F)	0.000	0.000	0.000
Akaike criterion	−532.79	−530.79	−527.04
Schwartz criterion	−527.68	−518.02	−509.16
Ramsey test (RESET) (squares), *p*-value	0.826		
LM test, *p*-value	0.905	0.616	0.615
White's test, *p*-value	0.309	0.863	0.879
Breusch–Pagan test, *p*-value	0.504	0.002	0.018
ARCH processes test, *p*-value	0.861	0.051	0.138
Normal error distribution test, *p*-value	0.785	0.872	0.858

The standard error of all regression equations for this portfolio is less than the standard error of regression equations for carbon and carbon-free portfolios. But, the adjusted R^2 is small. The Ramsey test shows the adequacy of the linear specification for all equations. There is no autocorrelation of residuals in all regression equations. ARCH processes are missing. The residuals are normally distributed. In the presence of heteroscedasticity, estimates in the Newey–West form are used.

We assess the existence of the carbon premium in the Russian stock market. The size and significance of the carbon premium are the focus of our empirical analysis. In general, we draw the following conclusions. Hypothesis H1 cannot be rejected according to the results of the empirical analysis. In the Russian stock market, the carbon premium (i.e., the alpha of the "carbon-minus-carbon-free" portfolio) is statistically significant at the level of 1%; its value averages 6.2% per year for the analyzed sample period. The alpha of the carbon portfolio is higher than the alpha of the carbon-free portfolio. The empirical analysis did not support the H2 hypothesis. The CO_2 beta and the cost beta are not statistically significant; therefore, they do not affect the carbon premium (the "carbon-minus-carbon-free" portfolio returns). Research hypothesis H3 is empirically confirmed only in part. The "carbon-minus-carbon-free" portfolio returns (or carbon premium) are sensitive to the market premium only. In general, the carbon premium is statistically significant in the Russian stock market, but changes in CO_2 emissions and air protection costs do not affect its value.

4. Discussion

Currently, there is considerable uncertainty in Russia regarding various aspects of the national climate agenda, in particular, the development of an Emissions Trading System. The creation of a new carbon trading market is a pressing issue for Russia. The demand for carbon units from air-polluting firms is an important condition for its effective development. Various factors influence the demand. One of them is the presence of a carbon premium in carbon firms' stock returns. Other things being equal, firms emitting CO_2 are exposed to carbon risk and therefore require a higher expected return compared to non-carbon emitting firms. We link carbon risk to CO_2 emissions and air protection costs. They affect the cash flow generated by carbon firms and hence the price and the stock returns.

This article fills a gap in the literature by providing a comprehensive empirical assessment of whether the stock returns of Russian companies that emit CO_2 in the course of their operations and spend on air protection significantly outperform the stock returns of companies that do not. In particular, we examine the impact of CO_2 emissions and air protection costs on the stock returns of carbon firms and carbon-free firms. We evaluate the size and significance of the carbon premium, which is defined as the excess of carbon portfolio returns over carbon-free portfolio returns using an asset pricing methodology.

Our main conclusion is that there is a statistically significant and positive carbon premium in the Russian equity market, averaging 6.2% per annum. This suggests that carbon firms show higher returns. The carbon premium is sensitive to the market premium in the conditions of the Russian financial market. Relative changes in CO_2 emissions and air protection costs do not have a statistically significant impact on it (CO_2 beta and cost beta for the "carbon-minus-carbon-free" portfolio are statistically insignificant). This allows us to conclude that the carbon premium is determined by other factors in the conditions of Russia. The identification and evaluation of these factors is a direction for further research. Our analysis contributes to the study of Russian environmental policy because it informs policymakers and investors about the implications of current CO_2 emission regulation. We conclude that without environmental regulation, companies that maximize shareholder value have little incentive to reduce the negative impact on the environment. The experience of foreign countries shows the main driving force for the implementation of air protection projects is carbon emissions trading systems with an adequately high level of CO_2 prices together with state incentive measures. We see the study of the impact of tax policy and the efficiency of air protection costs as a direction for future research also.

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