

IMPACT OF CARBON EMISSIONS AS ANTI-ESG FACTOR ON THE PERFORMANCE OF FINANCIAL MARKETS IN CHINA

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Abstract

The article researches the impact of anti-ESG factors on financial markets in China and its consequences for the countries of Central Europe. In this connection, the specific aim of the article was to analyze whether CO₂ emissions, as the main factor against ESG concept, negatively affect the return of stock and bond investments in the extreme environment of the world's largest producer of emissions - China. The multiple linear regression (MLR) model method was used for explaining the investment return according to Khan's and Long's model specification, applied on annual data for investment horizon from 1991 to 2023. The results at the 5% level of significance ($p < 0.05$) surprisingly showed that emissions have a positive impact on Chinese stock prices ($\beta = 0.079$). This reflects that instead of environmental goals stock investors in China rather have a preference for economic growth, for which China's emission-intensive industry is crucial. On the other hand, ESG-related issues have a slightly negative impact on bonds ($\beta = -0.031$), which emphasizes the greater importance of environmental factors for fixed income investments. Overall, the research offers valuable insights into the complex relationship between CO₂ emissions, investment performance and investor sentiment in China, which may have significant implications for other countries subject to strict ESG regulations, as well as the potential to use ESG strategies to increase the attractiveness of their financial markets.

Implications for Central European audience: Understanding the impact of CO₂ emissions on Chinese financial markets, holds significant implications also for Central European countries, as ESG is at the forefront of EU regulatory framework. Particularly within the Visegrad 4 (V4) alliance, where industrial production in sectors like car manufacturing plays a crucial role in economy, finding a balance between economic growth and environmental responsibility is paramount. The article therefore implies that by integrating ESG in investment strategies, Central European countries can possibly enhance the attractiveness of their currently passive financial markets. At the same time the findings help societies as a whole, by emphasizing the financial benefits of building a more sustainable future.

Keywords: green finance; ESG investment; carbon management

JEL Classification: G11, Q51

Introduction

The concept of ethics and sustainability began to appear more frequently in economics at the end of the 60s of the last century and has experienced a rapid rise since then. More and more scientific evidence has begun to surface, emphasizing that human activities affect ecosystems and approach a turning point, at which the so-called carrying capacity of the planet could be exceeded, the climate system could potentially be destabilized and thereby threaten the future viability of the Earth. Understandably, climate change is thus considered one of the biggest environmental risks currently affecting humanity (Schoenmaker & Schramade, 2019). The crisis related to the COVID-19 pandemic in 2020 also further underlined the importance of recalibrating time horizons in economic strategies from the overly short-termism, typical for the pre-pandemic period, to more long-term scenarios. It is therefore no surprise that increasing amount of entities are currently considering longer-term plans to ensure the health of the planet for the generations to come.

Along with this global transformation towards sustainability, the acronym ESG was defined, which includes a complex of environmental, social and management principles. In its application to investing, the term ESG investing arises, representing the inclusion of non-financial factors in the process of identifying a suitable investment (Hill, 2020). Investor interest in these kind of investing has increased in recent years, as many institutions and individuals are trying to address global climate threats through their investments, just as they are doing it through changes in their consumer behavior and purchasing habits.

As this shift towards sustainability has gradually been reflected in economic strategies around the world, it also calls for a closer look on financial markets. And since China is the main contributor to global emissions (Read, 2023), as well as bearer of significant financial influence, the importance of understanding the relationship between emissions and investments in such environment of extreme conditions has become the subject of our research. The purpose of this article is specifically to test the impact of CO₂ emissions as an anti-ESG factor on the performance of financial markets, which in the context of ongoing urgency of climate change makes it a vital part of exploring ways to support sustainable finance. Based on our testing whether poor ESG practices discourage investors in an industrial country like China, other countries and companies could be motivated to adopt greener practices, and policymakers might be encouraged to introduce more effective financial regulations. Our findings are thus intended to offer insights and potentially serve as a full-fledged inspiration for other countries, including European ones, where sustainability is at the forefront. Such knowledge can be valuable for both governments and investors seeking to balance financial and environmental goals. Last but not least, the research contributes to the literature by addressing a relatively unexplored topic, particularly in the context of Chinese market and its unique challenges.

The main difference from previous research therefore is the focus on the so far little-researched Chinese investment environment, as well as the fact that we use data until the end of 2023, which includes the for financial markets very volatile period of the COVID-19 pandemic. In addition, the research also adds a comparative aspect of how differently emissions affect Chinese stocks and bonds, a valuable dimension vastly missing from the more comprehensive prior research covered in the literature.

1 Literature review

1.1 ESG concept and its relation to emissions

ESG (abbreviation from Environmental, Social and corporate Governance) is a complex term that refers to three frameworks, namely the environmental framework, the social framework and the framework associated with corporate governance (Albuquerque et al., 2019). They are designed to be integrated into the organization's strategy with the intention of expanding its goals in a way that they include the management related to sustainability (Ozili, 2022). Pucker and King (2022) from Harvard University also describe it as a concept that helps stakeholders understand how an organization manages risks and opportunities related to environmental, social and governance criteria. In this context, the activity of ESG investing can be simply defined as investing that, in addition to profit maximization also prioritizes optimal environmental, social and governance results (Hill, 2020). These factors are then a crucial part of the process to look for non-financial metrics that likewise contribute to market valuation (Giese et al., 2019).

In terms of previous scientific research, ESG factors have been generally identified as key factors in investment decisions (Fрати et al., 2022; Mo et al., 2021). Within the three pillars of ESG, most attention on financial markets is given to the environmental component, in particular to emissions (Galema et al., 2008). Carbon production and pollution is in this sense heavily prioritized before other environmental factors such as energy consumption, water scarcity, biodiversity and deforestation (Agliardi et al., 2023). Indeed, high levels of CO₂ emissions are generally considered a key negative factor in ESG assessments (Khan et al., 2016). Carbon emissions have long been a significant concern within the broader ESG framework, which reflects a company's environmental impact and sustainability practices (Eccles & Serafeim, 2013). These emissions thus have far-reaching implications for investment performance, as they are associated with regulatory, reputational, health and transition risks (Zhou & Li, 2019; Grewal & Serafeim, 2020).

1.2 Impact of emissions on return on investment

Past studies examining the relationship between CO₂ emissions and return on investment reveal a predominantly negative correlation. Companies with high emissions face increased regulatory scrutiny, leading to compliance costs and potential profitability problems (Busch et al., 2015). Such firms are also more vulnerable to reputational damage and consumer backlash, which affects their market share and sales (Fombrun & Shanley, 1990; Stanwick & Stanwick, 1998). During the COVID-19 pandemic, emissions reductions due to lockdowns, particularly in sectors such as transport, travel and manufacturing, temporarily moderated this immediate impact of emissions on investment (Le Quéré et al., 2020). In addition, Ouchna's (2023) systematic literature review further deeply analyzed the previous literature regarding the global impact of greenhouse gas emissions and green innovation on financial performance of corporate investors, thus contributing to the overall understanding of the financial effects of environmental factors.

More recent studies, such as Lee et al. (2023), showed that the impact of emissions on investment assets can also differ according to the specific type of investment. Government bonds that are directly linked to the country's politics and economic performance may show a higher impact of emissions, especially in cases where the country's environmental focus

affects its investment creditworthiness. Research by Eskander and Fankhauser (2023) illustrates how government emission policies can significantly affect government bond yields, while the impact on other financial markets may be more closely related to broader economic factors. These findings emphasize the importance of taking into account the dynamics of a specific asset class when evaluating the impact of emissions on investments, which will also be applied in our research from the point of view of separately examining bonds and stocks.

In addition, this negative impact of emissions goes beyond the environment of only financial markets and extends to the wider business environment. Companies operating in jurisdictions with inadequate enforcement mechanisms may face increased operational risks in the future, including sanctions for non-compliance with international regulations, supply chain disruption and litigation costs (Sharfman & Fernando, 2008). As a result, companies are forced to integrate emissions management strategies into their business models to mitigate risks, increase resilience and ensure long-term value creation.

1.3 Specifics of emission production in Chinese economy

As the world's largest producer of CO₂ (Hu et al., 2024), China represents a unique case for investigating the impact of emissions on investment. The Chinese government has already recognized the urgency of solving environmental problems and initiated efforts to transition to a greener economy (Wu et al., 2019). Even so, new analysis for Carbon Brief based on official figures and commercial data, shows that China's CO₂ emissions continued to rebound from the nation's "zero-Covid" period, rising by an estimated 4.7% year-on-year in the third quarter of 2023 and surpassing 4 billion metric tons for the first time in history.

The transition to more ecological alternatives, following the industrial character of the country, thus naturally represents significant future consequences for investors in China. The evolving global policy environment emphasizes emissions reductions, which may negatively affect some Chinese industries that are heavily dependent on high emissions, such as coal and heavy manufacturing (Stoerk et al., 2019). At the same time, these changes are associated with rising compliance costs, leading to potential problems in the performance of Chinese stocks and bonds (Wen et al., 2020). Investment companies investing in emission-intensive industries may thus face increased vulnerability to financial losses during the global sustainability transition, which may have a negative ripple effect on Chinese financial markets (Eccles & Serafeim, 2013; Flammer, 2012).

Research further suggests that Chinese firms with robust ESG performance are more likely to attract investment capital and achieve sustainable financial performance (Cheng et al., 2014). Indeed, investors in Asia are increasingly recognizing the severity of environmental risks and incorporating ecological considerations into their investment decisions (Zenno & Aruga, 2024). Furthermore, China's persistent emission-related environmental problems, such as air pollution, vulnerability to climate change, and resource depletion, may also discourage foreign direct investment (FDI) and hinder future economic development prospects (Green & Stern, 2017). As a result, policy makers in these countries are under an increasing pressure to implement strict emission reduction measures and promote sustainable business practices in order to increase their global competitiveness and attractiveness to investors.

However, it is essential to state that there is a significantly limited body of literature that specifically focuses on the impact of emissions on investment in China. In this case, similar industrialized Asian countries such as Japan and South Korea can provide valuable comparative insights into the relationship between emissions and investment in this region. High emissions in certain sectors in South Korea and Japan lead to problems including reputational risks and regulatory hurdles, but overall the impact of emissions volumes in this region is ambiguous (Khue et al., 2022; Kim & Park, 2021; Okajima & Okajima, 2016). Despite the high degree of industrialization, both South Korea and Japan have demonstrated resilience of their economies and financial markets, which reflects their ability to balance the high emission intensity of local industries with the ongoing high demand from their global trading partners and the environmental efforts of other sectors also included in their national stock indices (Arefeen & Shimada, 2020; Khue et al., 2022).

What is interesting is that despite the fact that China is the world's leading producer of CO₂, the Chinese stock markets has not shown a consistent and substantial decline over the last century. In fact, China's rapid economic growth and industrialization often mask the immediate market consequences of its activities with high emissions (Noh & Park, 2023). While concerns about environmental risks and climate change have increased globally, Chinese stock markets have shown some resilience and adaptability at times, reflecting the complex interplay between economic development, government policies and investor sentiment (Ren et al., 2022). This historical trend underscores the complexity of this relationship and highlights the need for continued research in assessing the long-term effects of emissions on China's investment environment.

In this context, we base our research on the hypothesis that investors today take ESG factors more into account, which means that they are less interested in investing and doing business in countries with high CO₂ emissions production. By applying it in the conditions of the Chinese financial markets, we can test this hypothesis in extreme conditions, where the resulting dependencies should be stronger. If the hypothesis that investors have a negative perception of the extent to which China produces high emissions is confirmed, the research results can serve as a motivation to perform more elaborate ESG practices in other countries as well.

2 Methodology and data

The conducted empirical research is aimed on examining and quantifying the impact of CO₂ emissions on the return of Chinese investments, with an emphasis on the differentiation between Chinese stocks and bonds. On this basis, the research seeks an answer to the research question: "Does the volume of CO₂ emissions, as the main anti-ESG factor, have a negative impact on the return of Chinese investments?". The results aim to provide a deeper understanding of the relationship between environmental factors and financial markets within the extreme environment of China, as the world's largest carbon producer.

Based on the secondary review of the literature summarized in the previous part of the article, two hypotheses were formulated that will be tested in our research:

- **H1:** *The volume of CO₂ emissions has a negative effect on the return of Chinese investments (both stock indices and bonds).* (Reference: Busch et al., 2015; Ouchna, 2023; Wen et al., 2020)

- **H2:** *The volume of CO₂ emissions has a more negative impact on the yield of Chinese bonds than stocks.* (Reference: Eskander & Fankhauser, 2023; Lee et al., 2023; Noh & Park, 2023)

The used sample of data has the character of time series within the researched investment period from 1991 to 2023. The examined data sample thus consists of 33 annual observations.

The dependent variable (y) represents the return from the investment asset, in our case stock shares or bonds, while the main independent variable (x) will be the volume of CO₂ emissions, as the most significant part of overall greenhouse gas (GHG) emissions. The dataset includes historical volume of fossil CO₂ emissions (CO₂ emissions from energy use, combustion and industrial processes), methane (CH₄ emissions from solid waste, coal and lignite mining, rice fields, agriculture and leaks from gas pipelines) and nitrogen oxide emissions (N₂O emissions).

In addition to the variables for the volume of CO₂ emissions, financial data for the return of investment assets and a set of control variables appearing in the extended model of the return-on-investment assets, as previously presented by Khan and Zaman (2012) and Long et al. (2024), were also used. The set of main variables of our research consists of:

- *emission_total* → annual volume of CO₂ emissions in China (Source: EDGAR - The Emissions Database for Global Atmospheric Research, 2024),
- *emission_change* → year-to-year change in CO₂ emissions volume in China (calculation using the formula $CO_{2_total,t+1} - CO_{2_total,t}$),
- *HSI_return* → annual return of Hang Seng stock index (Source: Yahoo Finance, 2024),
- *CGB_yield* → annual yield of Chinese 10-year government bonds (Source: Bloomberg, 2024).

Macroeconomic data drawn from the economic database of the Federal Reserve Bank of St. Louis (2024) and the National Bureau of Statistics of China (2024) were also used as control variables:

- *GDP_growth* → annual GDP growth (in percentages) in China,
- *unemployment* → annual unemployment rate (in percentages) in China,
- *oil_price* → average annual price of oil,
- *inflation* → average annual inflation rate (in percentages) in China,
- *interest_3m* → annual average of 3-month interest rates in China.

Regarding the scientific research methods used, this study employs a three-step approach for analyzing the relationship between CO₂ emissions and financial market performance. Firstly, a graphical analysis is conducted to visually examine the development of the two variables over time. This approach involves plotting time-series data of CO₂ emissions and investment returns on a graph to observe their respective trends and fluctuations. By visually inspecting the plotted data, potential patterns, trends, or anomalies can be identified, providing initial insights into whether the relationship between emissions and financial market performance exhibits reverse trends.

Next, a Pearson correlation matrix is calculated to quantify the strength and direction of the potentially linear relationship between CO₂ emissions and investment returns. Pearson correlation was chosen over Spearman as it specifically measures linear relationships, which aligns with most financial studies and portfolio management practices often assuming linear dependencies. However, we acknowledge that nonlinear dependencies may exist, and future research could explore alternative methods, such as Spearman correlation, to capture potential monotonic relationships.

This statistical analysis using Pearson coefficient will provide us insights into the degree of association between the variables, helping to determine the presence and magnitude of any correlation within the 33-year time window. Investment correlations are mainly used in advanced portfolio management and are calculated through correlation coefficients like Pearson (r). The value of correlation coefficient varies between [-1.0 and 1.0] (Benesty, 2009). It is then noted that a result with a coefficient over 0.7 can be considered as a strong dependence, or moderate from the interval of 0.3 to 0.7.

To calculate this correlation, the following formula for Pearson coefficient was used:

$$r = \frac{\sum(x_i - \bar{x}) * (y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 * \sum(y_i - \bar{y})^2}} \quad (1)$$

Source: Benesty (2009)

Where r = Pearson correlation coefficient, x_i = independent variable and y_i = dependent variable.

Lastly, an econometric model is employed to examine the complex relationship between CO₂ emissions and financial market performance based on the time-series data, where t represents annual observations. Specifically, the Multiple linear regression (MLR) model with the method of ordinary least squares (OLS) will be used, which is suitable for this case, because it allows the quantification of the direct impact of emissions, while controlling the results for other economic factors that, according to economic theory, also naturally affect the return of investments.

As part of the initial determination of the direction of dependence, the OLS model was first used in its simplest form with only the emission change as its sole dependent variable. These models focused exclusively on the impact of only CO₂ emissions on investment returns, allowing us to examine the direct effects of emissions on financial performance.

In the next step we have expanded the simplified model, by incorporating additional control variables such as GDP growth, unemployment rate, oil prices, inflation and short-term interest rates, following the pattern of Khan and Zaman (2012) and Long, et al. (2024) investment models:

[1]. Extended OLS model for bond yields

$$CGB_yield(Y) = \beta_0 + \beta_1 * emission_change_t + \beta_2 * GDP_growth_t + \beta_3 * unemployment_t + \beta_4 * oil_price_t + \beta_5 * inflation_t + \beta_6 * interest_3m_t + \varepsilon_t \quad (2)$$

[2]. Extended OLS model for stock returns

$$HSI_return(Y) = \beta_0 + \beta_1 * emission_change_t + \beta_2 * GDP_growth_t + \beta_3 * unemployment_t + \beta_4 * oil_price_t + \beta_5 * inflation_t + \beta_6 * interest_3m_t + \varepsilon_t \quad (3)$$

Extended models capture the broader macroeconomic factors that can affect investment returns along with CO₂ emissions, making the model more realistic as it allows for a more comprehensive investigation of how emissions impact investment return, while accounting for potential confounding variables. All of the models have been implemented using econometric softwares, which enable a statistically approved estimation, testing, and validation of mathematical relationships.

Concluding the methodology, the final step of our econometric analyses involved conducting statistical tests to evaluate the quality and assumptions of the regression model. The tests encompassed assessments for multicollinearity, autocorrelation, and other diagnostics such as heteroscedasticity. By scrutinizing these aspects, alongside the explained multi-stage methodological framework, the study ensures the reliability and robustness of the results, aiming to provide as possible accurate insights into the relationship between CO₂ emissions and financial market performance.

3 Results and discussion

3.1 Descriptive statistics

The initial descriptive statistics for the three main variables of CO₂ emissions, stock returns and bond yields show an upward trend for all three represented variables, expressed by the positive value of the average accumulated over the monitored time period from 1991 to 2023. At the same time, this observation may tentatively indicate that these variables do not necessarily show the inversely proportional relationship assumed by us, which, however, requires further investigation through correlation analysis.

Table 1 | Descriptive statistics of the 3 main research variables

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|-----------------|-----|-------|-----------|--------|--------|
| emission_change | 33 | 5.525 | 4.901 | -2.334 | 15.839 |
| HSI_return | 33 | 0.153 | 0.469 | -0.654 | 1.656 |
| CGB_yield | 33 | 0.035 | 0.011 | 0.016 | 0.069 |

Source: Authors' own processing

3.2 Graphical analysis and data transformation

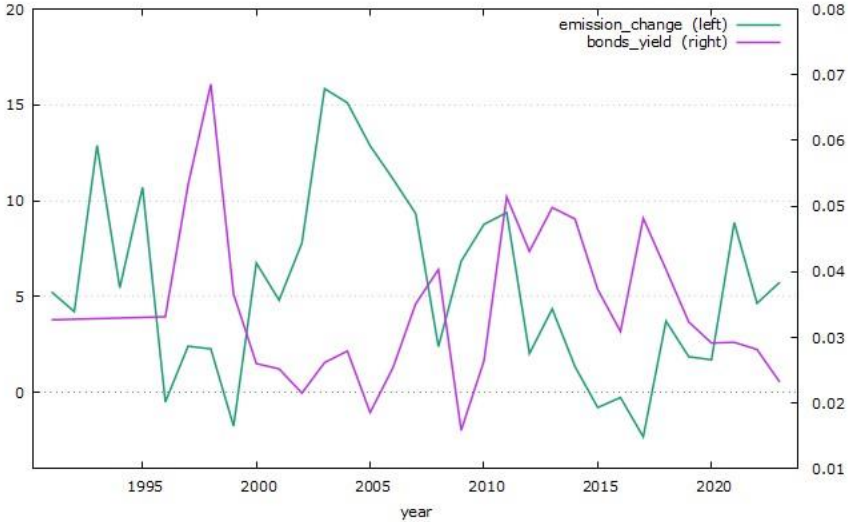
From the following graphical analysis of emissions and investment performance in Figures 1 and 2, multiple distinct patterns can be observed in the time series plots shown below.

In case of bonds, a recurring trend of reverse development is observed during multiple periods, notably from 1995 to 2000, 2000 to 2005 (after Dotcom bubble), 2008 to 2011 (after Global financial crisis), and from 2021 (during COVID-19 pandemic) onwards. These periods indicate instances where increases in emissions are associated with decreases in bond yields, suggesting a potential negative relationship as stated by our hypothesis H1 and previous literature (Lee et al., 2023; Eskander & Fankhauser, 2023).

Conversely, in the analysis of emissions and stock performance trends, several periods reveal simultaneous movements in the same direction for these two variables. Particularly,

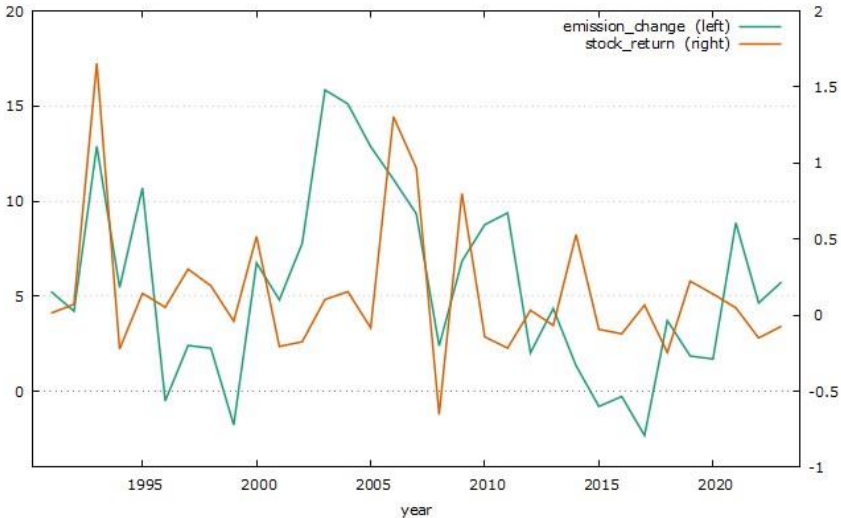
from 1992 to 1994, 2000 to 2008 (between Dotcom and Global financial crisis), and also in recent years, both emissions and stock performance exhibit parallel trends, indicating a possible positive correlation. This proposes that, unlike bonds, the negative impact of CO₂ emissions on stock performance may not be as strong, with economic growth and industrial activity exerting a stronger influence on investor sentiment, which has previously already been peripherally mentioned by Noh and Park (2023) and Ren et al. (2022).

Figure 1 | Development of China's CO₂ emissions and bonds yield in 1991–2023



Source: Authors' own processing according to data from Bloomberg (2024) and EDGAR (2024)

Figure 2 | Development of China's CO₂ emissions and stock returns in 1991–2023



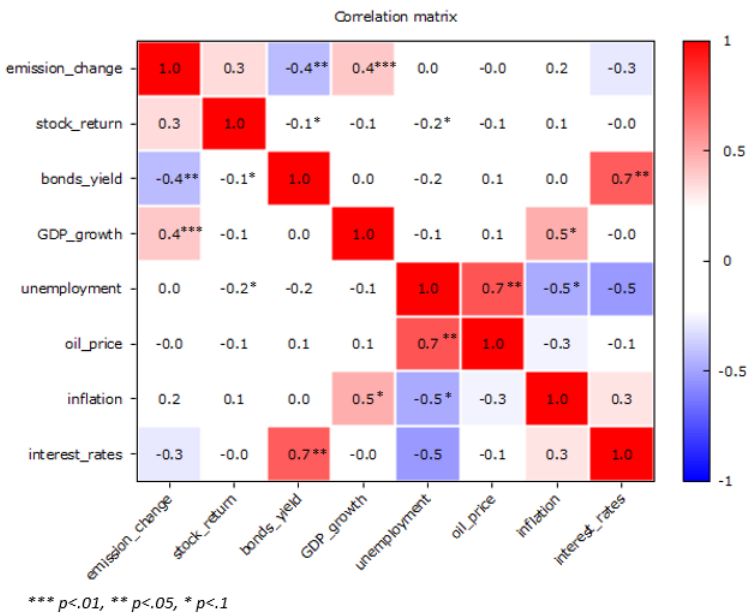
Source: Authors' own processing according to data from Yahoo Finance (2024) and EDGAR (2024)

As part of the opening data analysis, normality of the variables was further tested by means of a histogram, as well as the Skewness and kurtosis tests and the Shapiro Wilk test, which at $p > 0.05$ allowed us not to reject the null hypothesis and to confirm the normality of investigated data. Due to time series character of dataset, the stationarity (independence over time) was subsequently tested through graphical analysis and Dickey fuller test. However, as later shown in Table 4, it revealed presence of non-stationarity for all 3 main variables, lacking in white noise characteristics ($E(u_t) = 0$; $D(u_t) = \sigma^2$; $Cov(u_t, u_s) = 0$). It was therefore necessary to apply logarithmic transformation and first differentiation in order to achieve stationarity and to fulfill the basic assumptions of consecutive regression analysis.

3.3 Correlation analysis

Looking next at the Pearson correlation matrix (Figure 3) are further revealed several other noteworthy relationships between CO₂ emissions and selected financial and macroeconomic variables in China.

Figure 3 | Correlation matrix for participating variables



Source: Authors' own processing

As anticipated, there is a statistically significant negative correlation between the growth of emissions and bond performance ($r = -0.4$, $p < 0.05$), indicating that higher levels of emissions are associated with decreased bond returns. This aligns with previous expectations, as investors may perceive countries with higher emissions as riskier investments due to environmental concerns. In contrast, there is a slightly positive but not statistically significant correlation between CO₂ emissions and stock performance ($r = 0.3$, $p > 0.1$), which goes against the conventional hypothesis that high emissions are viewed negatively by investors. This positive correlation suggests that factors beyond environmental concerns may influence stock investors' perceptions more.

It is also worth mentioning the statistically significant positive correlation ($r = 0.4, p < 0.01$) between CO₂ emissions and Chinese economic growth (expressed through GDP), reflecting the strong relationship between industrial activity and emissions levels, particularly from production and transportation. Additionally, there is a slightly negative correlation between emissions and interest rates ($r = -0.2, p > 0.1$) that is not statistically significant, though it is in line with the premise that periods of higher interest rates are typically associated with lower emission production as companies borrow less and lower their business activities, aligning with conventional monetary policy theories.

Interestingly, the correlation matrix does not reveal any statistically significant relationships between emissions and other macroeconomic variables such as the price of oil, inflation, and unemployment. This kind of lack of correlation may be attributed to recent disruptions in economic theory, such as the breakdown of the Phillips curve relationship between inflation and unemployment. Specifically, during periods of higher rates and subsequently falling inflation globally, the expected rise in unemployment, as predicted by the Phillips curve, did not materialize. Additionally, speculative influences on the oil price, driven by oil concerns and investor speculations, may obscure its direct relationship with CO₂ emissions.

3.4 Regression model for bond investments

Following with the fitting of regression models for bond yields, first the simplified regression model indicated a weaker negative impact of CO₂ emission changes with a coefficient of $\beta_1 = -0.015$. But since according to the coefficient of determination (R^2) the model was able to explain only around 17% of the variability of bond yields, to avoid the problem of omission of a relevant variable bias (OVB), control variables were further added to the model as previously constructed by Khan and Zaman (2012) and Long et al. (2024).

After model expansion, the modified model (summarized in Table 2) confirms the negative influence at a significance level of 5%, with an increased regression coefficient at the level of $\beta_1 = -0.031$. This allows us to confirm our first hypothesis (H1) for the portion of bond investments. Overall, we can state that in the case of Chinese government bonds, a one percent increase in the volume of CO₂ emissions can lead to a reduction in the yield of bonds by approximately 0.00031 points. This indicates that higher levels of emissions are associated with decreased bond yield, supporting the findings observed in the graphical and correlation analysis. Based on the inverse relationship between bond yield and price, such reduction in yield typically leads to an increase in prices of existing bonds. However, from by us selected investor's perspective, lower yield implies a lower return of newly issued bonds, which may result in reduced future investor demand and ultimately make emissions negative to the bond market. This helps explain how bond investors may reduce their demand when yields are low, as they look for investments that provide higher returns (Liu et al., 2019). As already mentioned, based on these results investors probably perceive Chinese companies with higher emissions as worse investments due to environmental concerns, leading to sell-offs and consequently lower bond returns.

Additionally, the regression model shows a statistically significant negative dependence between Chinese bond returns and interest rates. This relationship importantly aligns with economic theory, particularly the Inverted Yield Curve phenomenon, where higher short-term yields signal economic uncertainty and reduced investor confidence in future growth. Similarly, the potential decline in 10-year yields due to emissions makes newly issued long-

term bonds less attractive to investors seeking higher income, reinforcing risk-averse behavior. This dynamic therefore further highlights the truly multilayered economic relationships shaping government bond yields in China.

Table 2 | Extended OLS model for bond yields (linear regression)

| CGB_yield | Coef. | St.Err. | t-value | p-value | [95% Conf. Interval] | | Sig |
|---------------------------|----------|-----------------------------|----------|---------|----------------------|-------|-----|
| ln_emission_change | -0.031 | 0.002 | -2.267 | 0.035 | -0.010 | 0.000 | ** |
| GDP_growth | 0.005 | 0.001 | 1.841 | 0.081 | 0.000 | 0.001 | ** |
| unemployment | 0.003 | 0.001 | 2.359 | 0.091 | -0.003 | 0.014 | * |
| oil_price | -0.005 | 0.072 | -0.919 | 0.374 | 0.000 | 0.000 | |
| inflation | -0.704 | 0.021 | -1.173 | 0.258 | -0.001 | 0.000 | |
| interest_rates | 0.039 | 0.002 | 4.611 | 0.007 | 0.004 | 0.011 | *** |
| Constant | -0.006 | 0.019 | -0.331 | 0.746 | -0.047 | 0.034 | |
| Mean dependent var | 0.034 | SD dependent var | 0.012 | | | | |
| R-squared | 0.717 | Number of obs | 31 | | | | |
| F-test | 8.447 | Prob > F | 0.000 | | | | |
| Akaike crit. (AIC) | -183.947 | Bayesian crit. (BIC) | -174.876 | | | | |

Note: *** p<.01, ** p<.05, * p<.1

Source: Authors' own processing

Apart from this, the extended model shows a higher quality of the model, as indicated by the high value of the F-test (8.447), and t-value > |2|, as well as a higher value of the already mentioned coefficient of determination R^2 , which indicates that the extended model was able to explain up to 71.7% of the variability bond yields, implying significantly higher explanatory power of this model.

3.5 Regression model for stock investments

In the case of the regression model for stock returns, first of all, the simplified model with only 1 independent variable showed a positive association between CO₂ emissions and returns with a regression coefficient of $\beta_1 = 0.033$. With the explanatory power of the model at the level of 11%, however, such results could again not be considered credible, and to increase

the relevance of the model, the model was likewise the previous case of bonds investment extended with a number of control variables.

By extending the model for stocks was the new model subsequently able to confirm this positive dependence and that with an even higher coefficient at the level of $\beta_1 = 0.079$. A unit increase in tons of CO₂ emissions thus contributes to a year-on-year increase in returns from Chinese stock investment by approximately 0.079 units. Based on this, our first hypothesis (H1) cannot be supported for the portion of stocks. At the same time these results confirm the second hypothesis (H2) of stronger negative effect on bonds, as bonds demonstrate at least a mild negative effect ($\beta_1 = -0.031$) while stocks show no negative effect all - in fact, a positive one. In this sense emissions seem to be related to a decrease in yields of new bonds, which reduces future demand from investors, while in contrast increases in stock returns may attract new investors looking for historical growth opportunities. We can consider this dependence to be statistically significant at the 5% significance level ($p < 0.05$), as is also the case with GDP variable, and at the 10% significance level ($p < 0.1$) also for the variable of 3-month interest rates.

These results suggest that higher levels of CO₂ emissions are associated with increased stock returns, indicating how Chinese stock investors prioritize economic growth over sustainability factors, compared to bonds where environmental practices in contrast help create a positive image of the country. This emphasis on economic growth is further driven by the fact that higher GDP stems from good financial performance and revenues of companies, which have a direct impact on their stock prices. Moreover, is this confirmed with statistically significant positive relationship between stock returns and GDP at the 5% significance level. This finding collectively accentuates the importance of economic growth in driving stock market performance in China, as higher GDP typically correlates with increased corporate profits and overall market optimism.

As previously mentioned, the extended regression analysis likewise reveals a statistically significant negative impact of interest rates on stock returns, at the 10% level. This negative relationship suggests that higher interest rates make it more expensive for companies to borrow money and conduct business activities, which is particularly relevant in light of the unprecedentedly high inflationary environment worldwide since the year 2022 with the following reaction of central banks to increase interest rates.

Table 3 | Extended OLS model for stock returns (linear regression)

| dif_HSI_return | Coef. | St.Err. | t-value | p-value | [95% Conf Interval] | | Sig |
|---------------------------|--------|-------------------------|---------|---------|---------------------|--------|-----|
| emission_change | 0.079 | 0.029 | 2.743 | 0.012 | 0.019 | 0.138 | ** |
| GDP_growth | 0.048 | 0.019 | -2.481 | 0.021 | -0.087 | -0.008 | ** |
| unemployment | -0.362 | 0.038 | -2.077 | 0.296 | -1.060 | 0.337 | |
| oil_price | 0.006 | 0.008 | 0.791 | 0.435 | -0.010 | 0.022 | |
| inflation | -0.029 | 0.030 | -0.970 | 0.340 | -0.091 | 0.033 | |
| interest_rates | -0.017 | 0.013 | 0.133 | 0.071 | -0.259 | 0.293 | * |
| Constant | 1.424 | 1.522 | 0.947 | 0.359 | -1.717 | 4.564 | |
| Mean dependent var | -0.005 | SD dependent var | | 0.734 | | | |
| R-squared | 0.359 | Number of obs | | 33 | | | |

| | | | |
|---------------------------|--------|-----------------------------|--------|
| F-test | 3.237 | Prob > F | 0.074 |
| Akaike crit. (AIC) | 68.050 | Bayesian crit. (BIC) | 78.087 |

Note: *** p<.01, ** p<.05, * p<.1

Source: Authors' own processing

Considering the qualitative evaluation of this model, just as in the case of bonds, the extended model was characterized by higher F-test values (3.237) as well as the desired high t-value > |2|. With the addition of relevant variables, it was naturally ensured that the coefficient of determination R² increased moderately to the level of 35.9% of the explained variability of stock returns, which, however, compared to the model for bonds at the level of over 71%, indicates that the return of stock assets is still affected by a larger number of market and non-market factors that were not yet fully included in the model.

3.6 Evaluation of models' quality and assumptions

Within the last part of the research process, a comprehensive ex-post model assessment was conducted to ensure the proper robustness and reliability of the extended regression models. As can be seen in Table 4, the original hypothesis H₀ is rejected at a critical value of 0.05 (5% significance level) and therefore accepts the alternative assumptions of model's stationarity, homoscedasticity, independence of residuals, as well as adequate specification of model variables according to the Ramsey RESET test methodology.

The only test prerequisite where the model happened to show hints of weakness is the occurrence of multicollinearity among the independent variables, utilizing the Variance Inflation Factor (VIF) method. While most variables exhibited VIF values within acceptable thresholds under the value of 10, several variables approached values close to 10. This finding is however still consistent with the logical explanation of intricate interrelationships between all economic variables within one economy, in our case Chinese economy, reflecting a complex dynamic throughout financial markets. While this proximity to non-compliance is still within the acceptable thresholds, it highlights possible opportunities for supplementary methodological refinement and future research efforts to enhance the understanding of this topic.

Table 4 | Test statistics for extended models at the 5% critical value

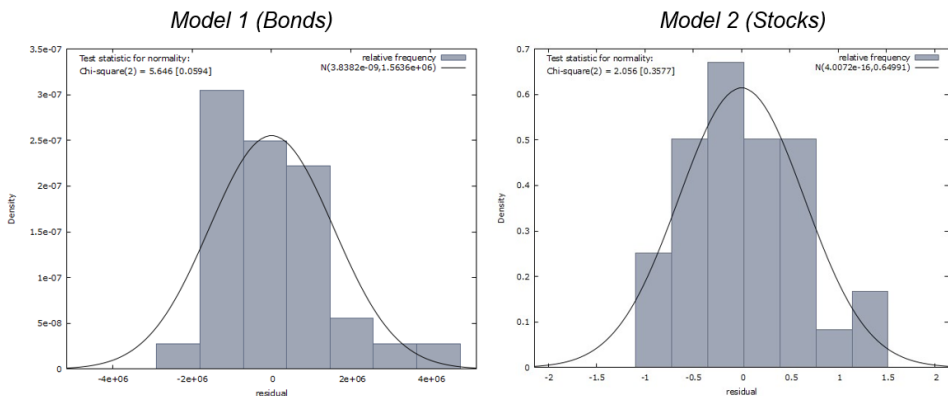
| Panel A: Statistical tests | Critical value | Model 1 (Bonds) | Model 2 (Stocks) |
|---|-----------------------|------------------------|-------------------------|
| Normality (Shapiro -Wilk test) | <0.05 | 0.000 | 0.000 |
| Distribution (Jarque-Bera test) | <0.05 | 0.000 | 0.000 |
| Stationarity (ADF-GLS test) | >0.05 | 0.071 | 0.071 |
| Stationarity (KPPS test) | <0.05 | 0.002 | 0.002 |
| Heteroscedasticity (White test) | <0.05 | 0.000 | 0.000 |
| Heteroscedasticity (Breusch-Pagan test) | <0.05 | 0.000 | 0.000 |
| Autocorrelation (Breusch-Godfrey test) | <0.05 | 0.001 | 0.001 |
| Model specification (Ramsey RESET test) | <0.05 | 0.001 | 0.001 |
| Omitted variable (OVB test) | >0.05 | 5.04e ⁻⁰⁷⁶ | 5.04e ⁻⁰⁷⁶ |
| Multicollinearity (p-value) | <0.05 | 0.007 | 0.007 |

Source: Authors' own processing

Despite the presence of multicollinearity challenges, the overall integrity and interpretability of the regression models remains intact. By addressing the assumptions of the models and acknowledging the relationships among variables, the research provides valuable insights into the complex interplay between CO₂ emissions and financial market performance in China. The findings therefore contribute to a deeper understanding of the factors influencing investment decisions, offering stakeholders and investors actionable knowledge for navigating the intersection of environmental considerations and economic imperatives in the context of financial markets.

In our final model evaluation was assed the normality of residuals distribution, which adherence to is vital for enhancing the accuracy of the model's predictions. A normal distribution of deviations is indicative of fewer extreme values, minimizing the disparity between actual values and values predicted within the OLS model and thereby enhancing the model's accuracy. As can be seen in Figure 4, both models residuals exhibited successful graphical representations of normality. However, for bonds pictured on the left, a more notable left-sided skew can be observed, which can potentially be attributed to the prolonged periods of zero interest rates that have been present on the global markets since year 2009 after the Global financial crisis and have led to the distortion of the low yield of bonds dependent on interest rates. Despite this skew, the graphical distribution of residuals for both stocks and bonds indicate a satisfactory approximation to normality, which completes the overall sufficient quality of both our conducted models.

Figure 4 | Normality of residuals distribution test



Source: Authors' own processing

3.7 Contribution of the results and its implications for countries of Central Europe

These research findings, overall indicating a negative impact of CO₂ emissions on bonds, but a positive one on stocks, offer valuable insights beyond the immediate context of China, with relevance for other countries as well, including the Central Europe and their respective financial markets. That is because these nations share similarities with China in terms of their

reliance on traditional heavy industrial sectors (Frydman & Rapaczynski, 1993; Wang et al., 2024). For instance, in Slovakia the automotive sector represents a substantial portion of the economy, Poland host significant coal mining and power generation industries, while Hungary's metallurgical and chemical industries, along with the Czech Republic's machinery and engineering sectors, are major contributors to both domestic and transboundary emissions. The interconnectedness of such emission-heavy industries across Central European countries makes it therefore crucial to address the by us found impact of CO₂ emissions on investment dynamics in this broader geographical region.

In the financial context, Central European countries exhibit distinct patterns of investment behavior compared to their Western European partners. While stock markets play a vital role in channeling investment capital in Western Europe, Central European nations demonstrate lower levels of stock market participation and numerous challenges in the bond market. Factors such as historical bad experience with fraud investment schemes, higher risk averse perceptions, geopolitical risks, stagnating economies, and demographic trends contribute to this disparity in investment behavior (Nicolescu & Tudorache, 2017). Additionally, to the industrial landscape, the regulatory frameworks within the European Union (EU) further accentuate the relevance of studying the impact of CO₂ emissions on investment decisions (Nesta et al., 2014). The EU has implemented very stringent regulations aimed at reducing carbon emissions and promoting sustainable practices across member states (Gafni et al., 2024). Another argument applicable in favor of conducting the empirical research in foreign environment is the ongoing data limitations prevalent in Central European countries. For instance, Slovakia's stock market, represented by the SAX index, exhibits low liquidity and limited trading activity compared to more developed markets, posing challenges for our intended comprehensive empirical analysis. Similarly, the scarcity of privately held data on bond trading further complicates research efforts. Central European economies however, similarly as China, face the imperative of significant emissions footprints (Magyari, 2023), which allows them to draw particularly important lessons from our research's results.

Firstly, the negative impact of CO₂ emissions on bond performance underscores the importance for Central European countries to mitigate risks associated with carbon-intensive industries, thereby improving the attractiveness of their bond markets that are the primary source of government financing and collective investing funds. Secondly, while the positive effect of emissions on stock investment may not translate to Central European markets identically like in China, due to differences in ownership structure and market composition, it shows the significance of also maintaining economic growth and industrial profitability for investors. This suggests that to further bolster stock markets and attract investor's interest, Central European countries could try to balance the current preference for ESG-friendly investments, while at the same time maintain their economically important industrial sector to ultimately stimulate growth in both financial and economic areas.

Furthermore, Central European policymakers and market participants can utilize the research findings to refine their investment strategies and market positioning. Recognizing the differing impacts of CO₂ emissions on bonds versus stocks, investors can adjust their portfolios accordingly to their preferences, allocating and diversifying capital to various sectors and companies that demonstrate strong ESG performance (being bonds) or resilience to environmental risks (being stocks). Moreover, policymakers can collaborate with market regulators and industry stakeholders to enhance transparency, disclosure standards, and

reporting mechanisms related to ESG factors, thereby fostering investor confidence and liquidity in both bond and stock markets.

All in all, the research findings regarding the impact of CO₂ emissions on financial markets in China definitely offer valuable wisdom for other countries seeking to improve the resilience, sustainability and attractiveness of their individual financial markets. That is because, as was just noted from our results, embracing ESG principles in a smart way, promoting green finance initiatives, and aligning investment strategies, can unlock new opportunities for growth and prosperity, while at the same time contribute to global efforts to address climate change.

Conclusion

As Environmental, Social, and Governance (ESG) considerations take center stage, currently overspilling also into the financial world, our research delved into how one of the most significant negative ESG factors of CO₂ emissions impacts the performance of financial markets in the currently world's largest CO₂ producer China.

Based on the results of our research can be concluded, that in contrast to the first hypothesis H1, the regression analysis did not support the statement that CO₂ emissions negatively affect the returns of all Chinese investment assets, which Noh and Park (2023) previously marginally hinted on in their study from OECD countries. Indeed, the regression coefficient of the emissions impact on stock returns showed a positive value of 0.079 at the 5% level of significance ($p < 0.05$). This can be attributed mainly to China's strong industrial production, which potentially outweighs concerns about the climate change among stock investors, especially in the midst of the expansion of the Chinese stock market driven by the country's rapid economic growth since the beginning of the 21st century. On the other hand, the volume of emissions showed a weaker but expected negative impact on the yield of Chinese 10-year bonds with a regression coefficient value of -0.031, based on which was confirmed the second hypothesis H2. In this sense, emissions can lead to lower yields of newly issued bonds, which reduces future investor demand and negatively impacts the bond market. Due to the fact that government bonds are subject to assessments that also directly take into account environmental factors, it is expected that one of the most direct environmental factors, such as in the research selected volume of CO₂ emissions, will also be reflected in the rating level of bond investments. The observed stronger negative impact of emissions here primarily results from their negative impact on Chinese bond ratings and the subsequent negative perception on the part of investors.

While the research findings shed light on the intricate relationship between CO₂ emissions and financial markets in China, their broader implications extend to other countries, including those in Central Europe. Given China's status as the largest producer of emissions globally, the results provide valuable insights, particularly in these extreme conditions where emissions are most intensive. While the direct applicability of these findings to Central European countries may vary due to differences in financial market characteristics, they generally underscore the importance of also implementing variations of sustainable investment strategies. These efforts not only align with global trends favoring sustainable investments, but can also contribute to long-term economic growth and environmental stewardship in the region. Thus, while the research may have been conducted in the context

of China, its implications resonate globally, emphasizing the need for collective efforts to address the challenges and opportunities posed by CO₂ emissions in the financial markets worldwide.

In the concluding remarks regarding the conducted research, it is lastly necessary to consider the potential limitations of the research, such as is a smaller number of observations due to the unavailability of data at a higher than annual frequency, or, in the context of the depth and complexity of the ESG concept, a too one-dimensional focus exclusively on CO₂ emissions and Chinese investments. A methodological limitation can also be the difference in the ability of the models to explain the variability of returns for stocks versus bonds. It is namely notable that stock markets with a much easier access to trading contain a correspondingly higher number of control variables that could further expand the model and improve its explanatory power. Additionally, due to the unavailability of more fragmented local data, we were unable to conduct analyses at the regional, sectoral, or company level, which could have provided more granular insights into the relationship between emissions and financial performance.

Future research may therefore examine data on a panel basis from multiple countries in order to recognize globally repeated investment patterns. Suitable as well would be to consider and compare a wider spectrum of remaining ESG factors beyond by us researched environmental pillar. Next research could in this sense take a contrasting approach by focusing on positive, so-called pro-ESG factors, such as the number of electric vehicles or the share of renewable energy, which are increasingly important not only in the Chinese context. The perspective of comparing developed and developing countries could also be upmosty interesting, as it is understandable that countries with a less developed economy often do not have sufficient resources to finance sustainability initiatives, and their influence on the financial markets thus probably presents only a very marginal priority. In addition, instead of the macroeconomic perspective applied by us, future studies could also expand the research in terms of microeconomic control factors through the analysis of the emissions effect on the shares of specific companies or their sales and profitability. Last but not least, along with the factors we have included, it would also be interesting to take into account more behavioral approach, with focus on factors such as the sentiment of investors and their specific environmental preferences, which could ultimately refine the topic even beyond the purely economic outlook.

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