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**Determinants of Carbon Prices: Insights from  
Nature-Based Global Emissions Offset Futures**

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**Abstract**

*Climate change is an important environmental issue for this generation. Carbon dioxide, the most predominant greenhouse gas, can remain in the atmosphere for decades or even centuries. Voluntary carbon markets are an important tool to mitigate climate change. However, carbon prices have been steadily decreasing, so it has become cheaper to pollute, reducing the incentive for polluters to assume alternative production methods. The objective of this article is to identify factors that affect carbon prices. This study employs multivariate ordinary least squares regression to examine the relationship between the prices of nature-based carbon offset futures contracts and various macroeconomic, financial, market, and policy factors. The results suggest that the prices of carbon offsets are positively correlated with the carbon efficiency of businesses index. Conversely, carbon offset futures prices exhibit a negative correlation with green bonds, the S&P 500 index, and the three-month Treasury bill secondary market rate. The findings indicate that green bonds and carbon offsets are possible substitutes. The results present insights for future policies that promote a well-functioning voluntary carbon market.*

*Key words:* futures markets, carbon offsets, voluntary carbon markets

*JEL codes:* C22, Q56

In the 1980s, people became aware of global warming and its implications after a multitude of experiments found evidence of it. This sparked a movement where people started to become more conscious of their greenhouse gas emissions. By 1990, the Acid Rain Trading Program was established as a cap-and-trade system to abate sulfur dioxide emissions. This program proved to be effective in eliminating emissions (Newell et al., 2012). The success of the Acid Rain Trading Program contributed to the development of the Kyoto Protocol, signed in 1997. The Kyoto Protocol initiated emissions trading and carbon markets (Newell et al., 2012). On August 1, 2021, the Chicago Mercantile Exchange (CME) Group launched a nature based global emissions offset futures market. Essentially, nature-based offsets are generated by agricultural projects, planting trees, and conserving forests that would be devastated otherwise. Many large corporations, who happen to be significant emitters, purchase these nature-based offsets to help achieve net zero emissions since they are unable to reduce their physical carbon footprint (CME Group, 2024a). Since this is a futures market, it allows emitters to hedge against their emissions risks. Emitters can establish long or short term positions, depending on the nature of their business operations. However, the lack of strict regulations induces emitters to question their trust in the market. On January 18, 2023, an expose was published in the media about the unreliability of carbon credit projects managed by a major player in the carbon offsets market (Greenfield, 2023), which claimed that over 90 percent of the carbon credits issued by it were “worthless.” People began to question the methodologies utilized by the registries to calculate and measure carbon. Furthermore, this incident raised skepticism about the effectiveness of the carbon market.

Despite a perceived lack of trust in the carbon market, it has been performing relatively well. The World Bank’s annual “State and Trends of Carbon Pricing 2024” report stated that \$104 billion was earned in revenue from global carbon pricing (The World Bank, 2024). Despite its large revenue, carbon prices have been decreasing. Carbon pricing has been affected by macroeconomic variables, policies, and energy crises, among other factors. It is imperative that carbon prices are optimal. This ensures that emitters committed to achieving net-zero emissions are incentivized to emit less carbon or purchase more credits. An optimal price of carbon is essential since it includes the costs of climate change in economic decision-making.

Carbon prices are supposed to reflect the social cost imposed on society. In his seminal work, Nordhaus (1992) proposed a framework for estimating an optimal carbon tax while considering the social costs. Other papers extended this approach to include the consideration for risk (Cai and Lontzek, 2019). Since the production of carbon is a negative externality due to its contribution to climate change, it is essential that it is priced properly. Carbon pricing addresses the market failure induced by production by holding participants accountable for their emissions. With decreasing carbon prices, polluters may not be paying for all the social costs imposed on society. Hence, low carbon prices might not reflect the true cost of carbon. Reduced carbon prices encourage polluters to emit more since they will be able to purchase more carbon credits. This will result in increased carbon emissions. With additional carbon emissions, global temperatures will continue to rise. Having identified the factors that contribute to carbon pricing, it will be possible to maintain proper carbon prices to combat climate change.

Previous studies have examined decreasing carbon prices in the European Union regarding their volatility. Chevallier (2011a) utilized retrospective and forward-looking tests to identify fluctuations in the stability of carbon prices. The authors found that there were significant shifts in 2007, 2008, and 2009 that are related to banking restrictions and uncertainty. They concluded that carbon derivatives are primarily used for hedging.

This article contributes to the existing literature by examining the factors that are associated with the prices of CBL Nature-Based Global Emissions Offset Futures (N-GEO), a relatively new carbon derivative product. I investigate the determinants of carbon pricing, including macroeconomic variables, commodity markets, and financial variables, among others. Ordinary least squares regressions were used to investigate the relationship between the prices of nature-based carbon offset futures and various macroeconomic, financial, market, and policy factors. The results suggest that green bonds and carbon offsets are substitutes. It was also found that the carbon-efficient index and carbon offsets have a positive correlation. A negative correlation was observed between carbon offset futures prices and green bonds, the S&P 500 index, and the three-month Treasury bill secondary market rate. The objective of this article is to identify the factors that contribute to the prices of nature-based global emissions offset futures contracts. The findings inform the formulation of policies to promote the development of the voluntary carbon credit market.

The remainder of this article is organized as follows: The next section is a review of related literature on carbon prices, followed by a description of the data used. Then, the methodology is explained, followed by the results and discussion. The article ends with a conclusion and final comments.

## **Background**

Economists agree that carbon pricing is necessary. However, there are debates regarding the calculation of the optimal price per ton of carbon. Although many agree with the framework set by Nordhaus (1992) for a socially optimal carbon tax, it is not always ideal when it comes to policy-making. Kaufman et al. (2020) suggests a near-term to net-zero carbon pricing system. The first step of this system is to choose a net-zero target date. Then, an emissions reduction pathway must be chosen, and carbon prices must be estimated while being consistent with the emissions pathway. These steps should then be updated periodically. The pricing estimates for carbon are predominantly influenced by policies and fluctuations in oil prices. This study supports that carbon prices are influenced by various factors, including policies and oil prices. Once determinants influencing carbon prices are identified, this method will be useful to society by improving future carbon price estimates.

There has been ongoing debate about the efficacy of carbon pricing. Boyce (2018) argues that carbon pricing encourages emission reductions in the short term and promotes cost-saving technologies over time. However, it is difficult to shape an effective carbon pricing system due to

uncertainty about the relationship between the quantity of carbon emitted and carbon prices. One view is that to be effective, there should be an emissions cap or a tax relative to the emissions target. Additionally, Boyce (2018) argues that it is difficult to implement carbon pricing in policy. For instance, a high carbon price could have a significant effect on fossil fuel prices, potentially resulting in unintended distributional effects that could affect income distribution. It is crucial to closely examine the determinants of carbon pricing so that their relationships can be clearly defined. This understanding will help shape carbon pricing policies that avoid unintended economic consequences.

Chevallier (2011b) explored macroeconomic factors and how they affect carbon pricing. It was found that economic activity is a critical determinant of carbon pricing. There is a significant relationship between carbon pricing and macroeconomic activity. Industrial production was found to have a more significant effect on carbon prices than macroeconomic, commodity, and energy variables. This article will add to Chevallier's work by employing ordinary least squares regressions to test and find more key determinants of carbon prices.

### **Data and Descriptive Analysis**

The principal variable of interest in this study is the weekly closing price of the nearby contract of CBL nature-based global carbon offset futures. The nature-based carbon offsets are solely derived from forestry, agriculture, and land use projects (CME Group, 2024a). Since these projects can sequester and reduce emissions, they are issued carbon credits that are equal to one metric ton of carbon dioxide that has been depleted or avoided. Given that this is a futures market, emitters must purchase these offsets in advance to hedge against their environmental risks and achieve their net-zero goals. The nature-based carbon offset contracts are listed for every month. The closing prices of the nearest unexpired contract on weeks ending on Fridays are considered.

Figure 1 presents the three time-series graphs that display the fluctuations in weekly carbon offset futures prices between July 30, 2021, and April 19, 2024. The figure shows the carbon price at the level logged and its log difference. Lagged data values were utilized to calculate the log difference for the nature-based carbon offset price data, rendering the variable stationary. The log differences represent weekly returns on nature-based carbon offset futures from July 30, 2021, until April 19, 2024. From this time series, it is evident that the carbon offset futures prices started declining around March 2022 after reaching a peak. This is noteworthy since this market launched in August 2021, and the nature-based carbon offsets continue to experience declining prices.

The independent variables used for this study cover different factors that are speculated to influence carbon prices. The macroeconomic variables include the real gross domestic product, real interest rate, break-even inflation rate, and the three-month secondary market rate of the Treasury bill. The break-even inflation rate is an indicator of expected inflation, calculated using the five-year Treasury constant maturity securities and five-year Treasury inflation indexed

constant maturity securities (Federal Reserve Bank of St. Louis, 2003). These macroeconomic variables were chosen to see if the economy's behavior influences the price of carbon. Futures closing prices for natural gas and crude oil contracts were also chosen for examination. These contracts are also weekly to ensure a more accurate correlation between carbon offsets and these variables. Natural gas futures contracts are prices for the first available natural gas contract for each week. Crude oil futures contracts represent the prices for the first available crude oil contract for each week (CME Group, 2024b). Natural gas and crude oil were chosen because as fossil fuels, they are expected to be highly correlated with nature-based carbon offsets. Additionally, the commodity variables chosen are final energy demand, commercial electricity prices, and global energy prices. The final energy demand is the producer price index by commodity for final energy demand (U.S. Bureau of Labor Statistics, 2009). The commercial energy prices are the average price of electricity to commercial consumers (U.S. Energy Information Administration, 2024). Global energy prices are the index of the global price of energy that is determined by the largest exporter of energy (International Monetary Fund, 1992). These factors were chosen to see if they affect carbon pricing since energy and electricity emit carbon dioxide.

Finally, various indices were examined, including the green bonds performance, Paris-Aligned ESG+, S&P 500, carbon-efficient, and global economic policy uncertainty. Green bonds track the performance of U.S. green-labeled bonds and their prices (S&P Dow Jones Indices, 2024). The Paris-Aligned ESG+ index measures the performance of eligible equity securities that are weighed to be compatible with the 1.5 degrees Celsius climate scenario at the index level (S&P Dow Jones Indices, 2024). The carbon-efficient index overweighs companies with lower levels of carbon emissions and underweights companies with higher levels per unit of revenue (S&P Dow Jones Indices, 2024). The S&P index represents the weekly index value at market close Federal Reserve Economic Database (2024b). The global economic policy uncertainty index shows the global economic policy index with the current price adjusted for GDP (Federal Reserve Economic Database, 2024a). These variables were selected because they are all suspected to have a correlation with nature-based carbon offsets. The global economic policy uncertainty index was chosen to determine if uncertainty has a correlation with carbon pricing, due to current distrust in the carbon market. The S&P 500 index was chosen because many global 500 companies participate in the carbon market, so it would be an interesting correlation to examine. Table 1 provides an explanation of these variables.

Data used in this study comes from diverse sources, including the London Stock Exchange Group (LSEG) Workspace, The Federal Reserve Economic Database, the U.S. Energy Information Administration, and S&P Dow Jones Indices. This data consists of weekly, monthly, and quarterly frequencies. The weekly data uses contracts ending on Fridays. Furthermore, the data examined is from July 30, 2021, until April 19, 2024. The variables with weekly data include nature-based carbon offset contracts, natural gas futures contracts, crude oil futures contracts, green bonds performance, break-even inflation rate, Paris-Aligned ESG+ index, the carbon-efficient index, and the S&P 500 index. The variables with monthly data consist of final energy demand, real interest rate, commercial electricity prices, global energy prices, and the

three-month Treasury bond secondary market rate. Finally, real gross domestic product is the only variable with quarterly data. Table 2 displays the descriptive statistics of these variables, including the mean, median, standard deviation, minimum and maximum values, and skewness.

Figure 2 displays the correlations between nature-based carbon offsets and the variables. From this correlation plot, it is observed that the variables highly and positively correlated with nature-based carbon offsets are natural gas futures contracts, green bonds performance, breakeven inflation rate, and global energy prices. It is intriguing that natural gas futures contracts and global energy prices appear to have a positive correlation with nature-based carbon offsets, despite natural gas being a fossil fuel, and these not being complementary goods. Natural gas is a primary input in the energy sector, so natural gas futures and global energy prices can be assumed to be highly and positively correlated with one another. This correlation matrix also shows that futures nature-based carbon offsets are highly and negatively correlated with gross domestic product, real interest rate, and the three-month Treasury bond secondary market rate. These correlations are logical because nature-based carbon offsets counterbalance the production of goods, and economic growth often leads to increased carbon dioxide emissions. Additionally, exchange rates can indirectly affect carbon pricing, and Treasury bills are another source of hedging market downturns. It is interesting to note that these three macroeconomic variables are observed to have a negative and high correlation with nature-based carbon offsets, suggesting their effect on carbon pricing. This will aid in proposing policies aimed at stabilizing carbon prices. These correlations will be further examined in this article.

Since the variables had different kinds of data, including weekly, monthly, and quarterly, the data had been aligned at the weekly level. The data merging process assigns the same values for the weeks belonging to the same months or quarters. This was done to avoid missing values in the data set.

## **Methods**

I used a multivariate ordinary least squares regression to model the relationships between nature-based carbon offset prices and the explanatory variables. I used two separate specifications for my regression equations.

### *Log Transformation*

I estimated the ordinary least squares regression using the logarithmic transformation in equation (1):

$$(1) \quad \log(NGEO_t) = \beta_0 + \beta_1 \log(NGEO_{t-1}) + \beta_2 \log(GDP_t) + \beta_3 RIR_t + \beta_4 TBILL_t \\ + \beta_5 IR_t + \beta_6 \log(NG_t) + \beta_7 \log(CL_t) + \beta_8 \log(GB_t) + \beta_9 \log(ESG_t) + \beta_{10} \log(SP500_t) \\ + \beta_{11} \log(CEI_t) + \beta_{12} ED_t + \beta_{13} \log(CEP_t) + \beta_{14} \log(GEP_t) + \beta_{15} \log(GEPUI_t) + \epsilon_t$$

The logarithm was applied to some of the variables to stabilize their variance. Another advantage of this transformation is that coefficients can be interpreted as relative percentage changes. The logarithmic transformation was not applied to the real interest rate, the three-month Treasury bill, the break-even inflation rate, or the energy demand. I ran four different versions of this equation. First, a simple univariate ordinary least squares regression was calculated with nature-based carbon offset prices and its lagged variable. Next, multivariate regression was conducted between nature-based carbon offsets and its lagged variable, gross domestic product, real interest rate, inflation rate, and the three-month Treasury bill secondary market rate. These variables were chosen for the second regression since they are macroeconomic variables. The next multivariate regression included the futures market variables: natural gas futures, crude oil futures, green bonds performance, Paris-Aligned ESG+ index, carbon-efficient index, and the S&P global 500 index. Finally, a fourth regression was conducted, adding in the rest of the variables in equation (1), including final energy demand, commercial electricity prices, energy prices, and the global policy uncertainty index.

### *Log Difference Transformation*

I conduct another set of regressions for log difference transformation using equation (2):

$$(2) \quad \Delta \log(NGEO_t) = \gamma_0 + \gamma_1 \Delta \log(NGEO_{t-1}) + \gamma_2 \Delta(IR_t) + \gamma_3 \Delta \log(SP500_t) \\ + \gamma_4 \Delta \log(NG_t) + \gamma_5 \Delta \log(CL_t) + \gamma_6 \Delta \log(GB_t) + \gamma_7 \Delta \log(ESG_t) + \gamma_8 \Delta \log(CEI_t) \\ + \gamma_9 \Delta \log(GDP_t) + \gamma_{10} \Delta(RIR_t) + \gamma_{11} \Delta(TBILL_t) + \gamma_{12} \Delta(ED_t) \\ + \gamma_{13} \Delta \log(CEP_t) + \gamma_{14} \Delta \log(GEP_t) + \gamma_{15} \Delta \log(GEPUI_t) + \epsilon_t$$

where,  $\Delta \log(P_t) = \log(P_t/P_{t-1})$  and  $\Delta P_t = P_t - P_{t-1}$  for any variable  $P$ .

Ordinary least squares regressions were used again to calculate the relationship between the nature-based carbon offsets and the variables. Log differences were used to measure the percent change over time of the variables. This shows if a large percentage change of a variable leads to a

percentage change in nature-based carbon offsets. The log differences of each variable were calculated by subtracting the lag of each variable from its log. Similar regressions were calculated but with log differences. The first log difference regression calculated was between nature-based carbon offsets and its lagged variable. The second regression is considered to be the preferred specification because it includes all of the weekly variables, ensuring more reliable log difference results. The final regression included all of the variables shown in equation (2).

All the data cleaning and calculations were conducted using R statistical software (R Core Team, 2023). The regression estimates were conducted through the *lmtest* package in R (Zeileis and Hothorn, 2002). The *tidyverse* package was used for the data wrangling and visualization (Wickham et al., 2019). The regression tables were exported using the *texreg* package in R (Leifeld, 2013).

## Results and Discussions

I present the regression estimates for equation (1) and equation (2) in table 3 and in table 4 respectively. Ordinary least squares regressions present the relationship between nature-based carbon offsets and macroeconomic, futures, and other variables. After conducting a multivariate regression of the log of nature-based offsets and the variables, it was found that the lag variable of nature-based offsets has an autocorrelation with nature-based offsets, exhibiting a significance level of one percent. This is significant since there is little variation between each offset price, and they change gradually over time. This can be shown in the time-series plot (figure 1) of the log of nature-based emissions offsets since its changes are always less than one dollar. As seen in table 3, the adjusted  $R^2$  value is 97.8% for the log transformation. However, the adjusted  $R^2$  value in table 4 is very small and even negative in some versions. It is notable that the log model fits the data well, whereas the log difference model is deemed to be a poor fit.

The coefficient of green bond performance is statistically significant at a 1% confidence level. This means that they have a significant correlation. It is interesting to note that green bonds have a significant correlation with carbon offsets, and the log and log difference coefficient is negative. Since the log coefficient is negative, it means that a one percent increase in the price of green bonds will lead to a 3.421% decrease in the price of carbon offsets. This is intriguing since they both aim to reduce emissions. Green bonds may have a strong relationship with carbon offsets because their prices move at the same time but in opposite directions. They may both share similar determinants since they share the same market. The market behavior seems to be the same for both nature-based carbon offsets and green bonds since their prices move in the same pattern. Many emitters that offset their emissions also purchase green bonds, so they will most likely experience similar market patterns. Emitters probably choose to invest more in green bonds when they are cheaper and purchase more offsets when they become cheaper. Hence, green bonds and carbon offsets may be substitutes. These results are consistent with Rannou et al. (2021), who also found that green bonds and carbon offsets are substitutes.

Furthermore, the coefficient of the carbon-efficient index is statistically significant at a 1% confidence level in table 3. The coefficient can be interpreted as a one percent increase in the

carbon-efficient index results in a 31.481% increase in the price of carbon. This relationship is likely strong since both aim to mitigate climate change. It is logical that they would exhibit a strong positive correlation, because both practices focus on entities eliminating their carbon footprints. It is important to note that their coefficient is high. This significance is relevant since the carbon-efficient index measures companies' carbon-to-revenue footprint, and purchasing carbon offsets reduces the footprint. This suggests that a significant amount of companies are lowering their emissions by purchasing offsets instead of switching to alternate production techniques.

The S&P 500 index is also statistically significant at a 5% confidence level. There is a negative correlation between these variables. This coefficient may be negative since not all of the companies included in this index participate in the carbon market. Another explanation could be that higher carbon prices might be negatively associated with the S&P 500 index since some constituents might be sensitive to carbon prices due to their business operations. The three-month Treasury bill also has a significant relationship with carbon offsets at a significance level of 10%. The coefficient is low and negative. This may be because Treasury bills allow hedging against market uncertainty, whereas carbon offsets allow hedging against climate risks. This is interesting since both hedging efforts are separate from one another.

The other variables with a negative correlation to nature-based carbon offsets are real gross domestic product, real interest rate, break-even inflation rate, Paris-Aligned ESG+ index, final energy demand, global energy price index, and the global policy uncertainty index. It is important to note that these values are not significant. It is reasonable that gross domestic product exhibits a negative relationship with carbon offsets as carbon offsets aim to incentivize entities to decrease their carbon emissions, which are mostly associated with production. Additionally, their coefficient is small, which is representative of the small percentage of participation in the carbon market. The real interest rate would have a negative relationship with carbon offsets since emitters would be more willing to purchase carbon offsets when the real interest rate is low. They are not highly correlated, as this behavior only holds for select emitters. Moreover, there is a small and negative relationship between the break-even inflation rate and carbon offsets. This is logical because an increased inflation rate will lead to emitters purchasing fewer carbon offsets. Greater inflation rates will lead to emitters being less able and willing to purchase offsets. However, most emitters that purchase offsets are wealthy and can still afford to purchase offsets with inflation, so they are not highly correlated with one another.

The Paris-Aligned index has a high correlation with carbon offsets. This is reasonable because the index focuses on decarbonization which can deter emitters from only depending on carbon offsets. There is a small and negative relationship between carbon offsets and energy demand. This can be explained by the fact that energy demand is generally considered to be inelastic. The global energy price index has a small and negative correlation with carbon offsets. This could be attributed to the energy sector's significant emission of carbon. So, when the price of energy decreases, more carbon offsets should be purchased. Finally, there is a negative

correlation between the global economic policy index and carbon offsets. This reflects the economic uncertainty that some have toward the carbon market and its policies.

The variables with a positive correlation to nature-based carbon offsets include natural gas futures, crude oil futures, and commercial electricity prices. These relationships are not significant. It is noteworthy that natural gas futures and crude oil futures are positively correlated with carbon offsets although it is not strong. This is unexpected because they are both fossil fuels. Therefore, when their prices decrease, carbon offsets should theoretically increase as emitters would need to offset more emissions. It is also notable that there is a slight yet positive relationship between carbon offsets and commercial electricity prices. As electricity generation is associated with emissions, a decrease in its cost should theoretically lead to increased purchases of carbon offsets.

## Conclusions

In this study, I examined the association of various economic, financial, market, and policy related factors on nature-based carbon offset prices. Using multivariate ordinary least squares regression, I found that most of these variables are not significantly correlated with carbon offset prices. However, I found that green bonds and nature-based offsets have a significant and negative correlation. This suggests that green bonds and carbon offsets could be substitutes. This finding is consistent with Rannou et al. (2021), who found that green bonds and carbon offsets are substitutes. This is reasonable because green bonds are used for long-term hedging, and carbon offsets are used for short-term hedging. I also found that carbon prices have a significant and positive correlation with the carbon-efficient index, a measure of companies' weights relative to their carbon-to-revenue footprint. This suggests that a significant amount of companies are decreasing their carbon-to-revenue footprint by purchasing offsets instead of switching to alternate production techniques. The results can be employed to inform how the nature-based global emissions offset futures product is being utilized. For example, it is evident that these contracts are being used as a practice of short-term hedging whereas green bonds are used for long-term hedging. With this information, the product can be further improved and developed.

These findings may be used to inform policy relevant to ongoing and future efforts to create voluntary markets for carbon. If carbon prices are low, then entities choosing to offset their emissions will be able to do so at a lower price, likely resulting in higher emission levels. This benefits polluters, contrary to the intent of carbon pricing, which is meant to disadvantage them. A decline in carbon prices would negatively impact carbon offset producers (e.g., landowners) because they would receive less money for the carbon sequestered by their trees. Since decreasing carbon prices increases emissions, the general public will be adversely affected. If carbon prices are optimal, then the general public will be better off since there would be less carbon emitted. Optimal carbon prices will help contribute to the climate change movement by discouraging carbon emissions through higher costs. If the price of carbon offsets is higher, it will deter emitters from emitting as much.

The findings also have implications for monetary policy. One interesting finding is that the three-month Treasury bill has a significant and negative correlation with carbon offset prices. This suggests that a lower Treasury bill rate is associated with a higher price of carbon offsets. In addition, a decline in carbon prices might have implications for participation in conservation programs that generate carbon offsets, such as cover crops.

There are several limitations to this study. While I have examined the factors associated with carbon offset prices, the findings of the study cannot be interpreted as causal. Furthermore, there could be omitted variable bias since factors such as market trust and policy stability are not accounted for in my models. Future research on this topic can go in several directions. It would be interesting to determine if any of the variables affect the volatility of carbon prices. In addition, using appropriate model selection methods such as the Least Absolute Shrinkage and Selection Operator (LASSO) regression might yield a more parsimonious model. Also, autoregressive models could be used to uncover causal relationships between the variables.

The determinants of green bonds require closer examination to determine if they share similar determinants with carbon offsets. This should be studied since they have a significant correlation with each other. Green bonds are similar to carbon offsets, because they both share the same goal of reducing emissions. However, green bonds fund projects aimed at reducing carbon emissions, while carbon pricing allows entities to offset and hedge against their emissions. Green bonds are a way for emitters to employ long-term hedging since they are a fixed-income investment. Carbon offsets are a practice of short-term hedging to offset their estimated future emissions. Since there is a significant correlation, I would like to investigate the determinants of green bonds and identify similarities with carbon pricing. They are most likely closely related since they have shared consumers who exhibit similar market behavior. The consumers most likely purchase more of whichever is cheaper or choose to practice short-term or long-term hedging. They may be substitute goods. This will be interesting future research to explore.

Overall, understanding the determinants of carbon offset prices is important, because carbon offsets are an important policy tool aimed at mitigating emissions while also providing emitters with a means to manage price risks. Carbon pricing is not perfect since it is a voluntary market with little regulation and trust. However, as this market becomes more regulated with policies that keep carbon prices high, it can be effective in reducing emissions by increasing the cost of offsetting carbon emissions.

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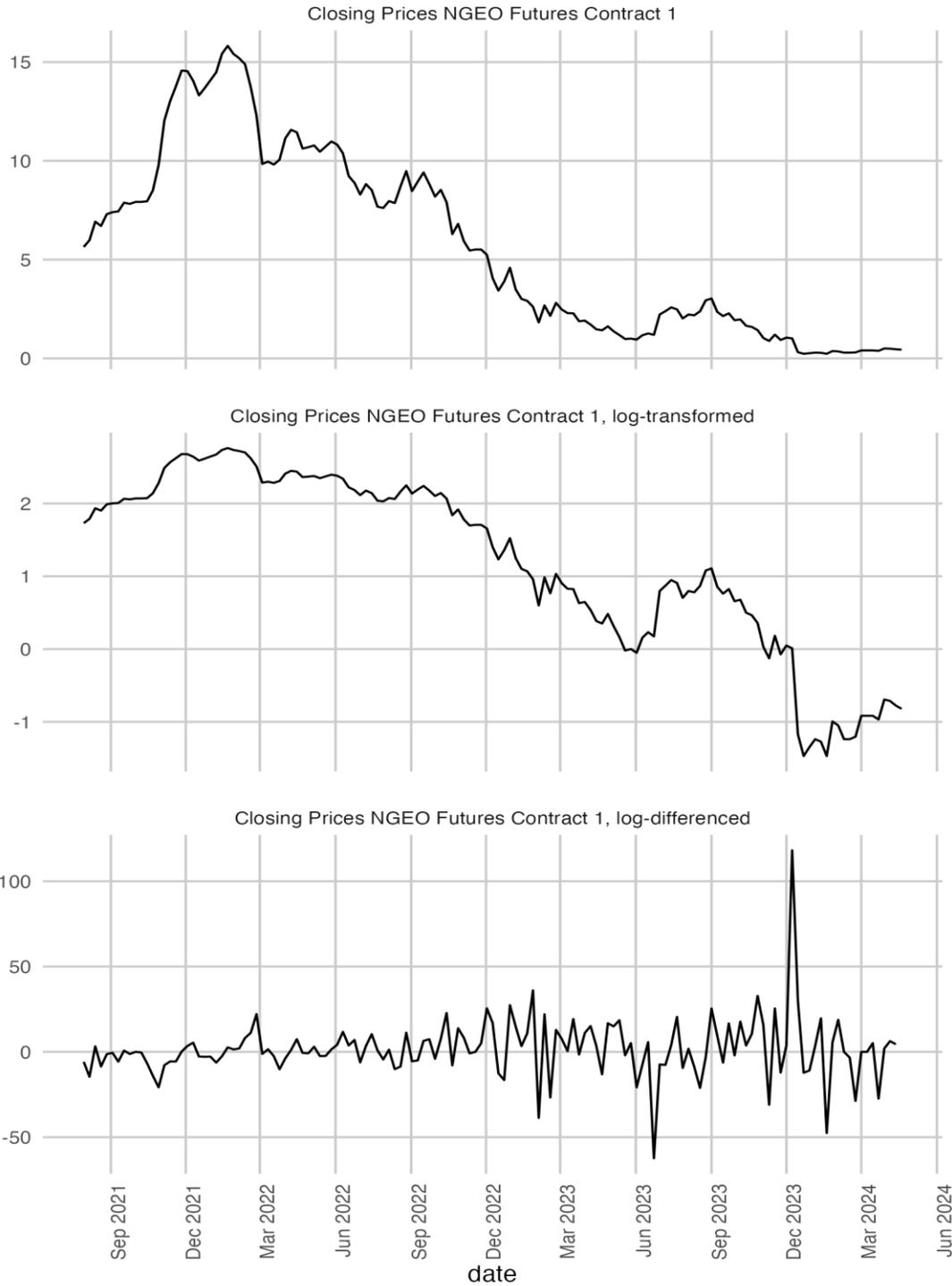


Figure 1: Time-series of carbon offset prices

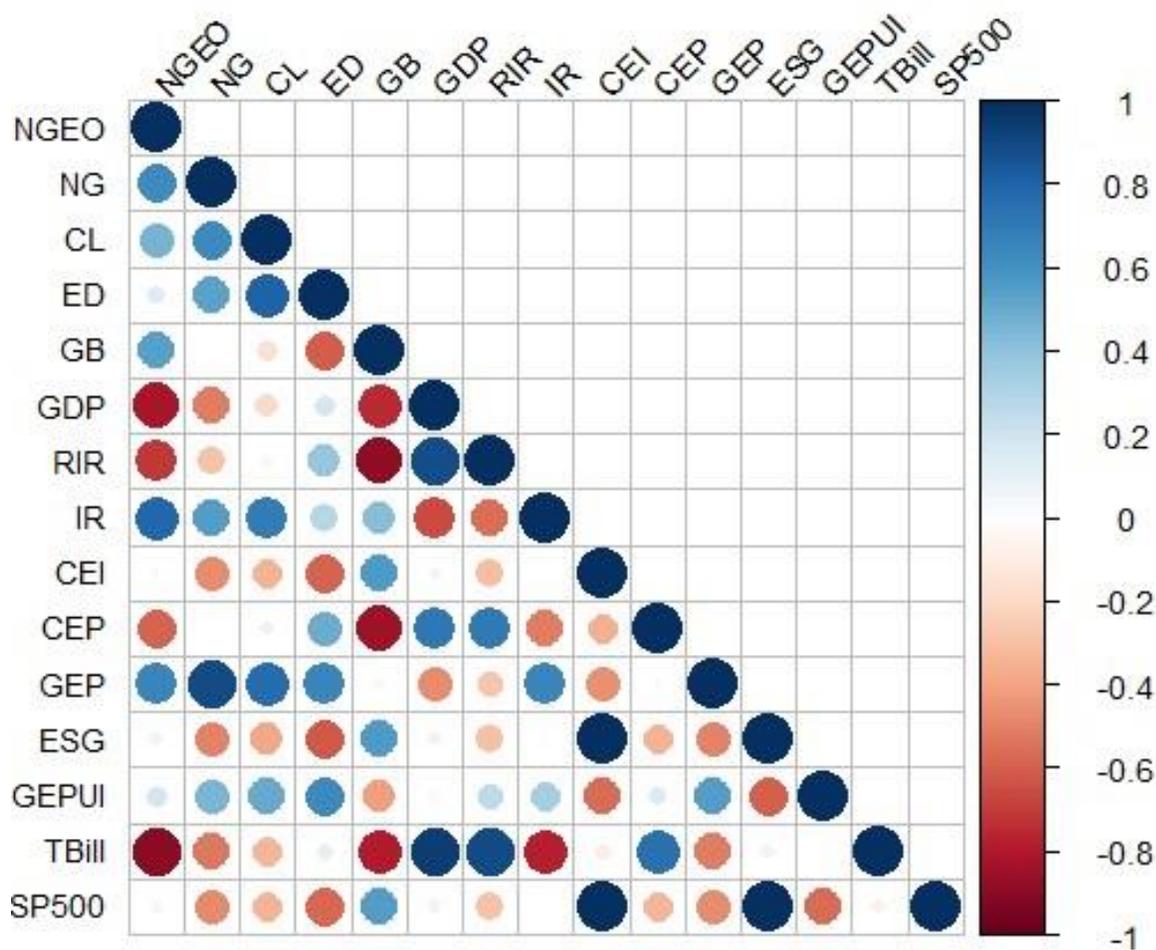


Figure 2: Correlation matrix of various factors affecting carbon offset prices

Note: Calculated using *corrplot* package in R (Wei and Simko, 2021) .

**Table 1: Description of Data Sources**

Variable	Description	Frequency	Source
NGEO	Closing prices of the first CBL Nature-based Global Emission Offset futures nearby contract	Weekly	LSEG Workspace
GDP	Real Gross Domestic Product	Quarterly	Federal Reserve Economic Database
RIR	Real Interest Rate	Monthly	Federal Reserve Economic Database
TBill	3-Month Treasury Bill Secondary Market Rate	Monthly	Federal Reserve Economic Database
IR	Break-Even Inflation Rate	Weekly	S&P Dow Jones Index
NG	Closing prices of the first available Natural Gas futures contract	Weekly	Energy Information Administration
CL	Closing prices for the first available Crude Oil futures contract	Weekly	S&P Dow Jones Index
GB	Green Bonds Performance	Weekly	S&P Dow Jones Index
ESG	Paris-Aligned ESG+ Index	Weekly	S&P Dow Jones Index
CEI	Carbon-Efficient Index	Weekly	S&P Dow Jones Index
SP500	S&P 500 Index	Weekly	Federal Reserve Economic Database
ED	Producer Price Index: Final Energy Demand	Monthly	Federal Reserve Economic Database
CEP	Average Commercial Electricity Prices	Monthly	Energy Information Administration
GEP	Global Energy Prices Index	Monthly	Federal Reserve Economic Database
GEPUI	Global Economic Policy Uncertainty Index	Monthly	Federal Reserve Economic Database

Table 2: Descriptive Statistics

	Descriptive Statistics					
	Mean	Median	SD	Min	Max	Skewness
Nature-Based Carbon Offsets Contract 1	5.95	5.51	4.60	0.23	15.82	0.46
Futures Natural Gas Contract 1	4.47	4.02	2.07	1.65	9.38	0.69
Futures Crude Oil Contract 1	83.18	79.56	12.46	65.07	120.44	1.10
Final Energy Demand	145.75	143.97	12.21	120.24	178.86	0.36
Green Bonds Performance Index	129.50	124.12	12.51	109.80	155.41	0.86
Real Gross Domestic Product	26293.36	26408.40	1291.55	23828.97	28255.93	-0.23
Real Interest Rate	1.15	1.42	0.70	-0.26	2.09	-0.56
Break-Even Inflation Rate	2.52	2.47	0.35	2.10	3.59	1.00
Carbon-Efficient Index	555.53	560.53	41.12	463.77	650.84	-0.05
Commercial Energy Prices	12.38	12.48	0.66	11.15	13.41	-0.34
Global Price of Energy Index	236.86	223.27	60.31	165.82	376.41	0.70
Paris-Aligned ESG+ Index	2072.78	2101.73	183.59	1685.39	2519.10	0.05
Global Economic Policy Uncertainty Index	251.98	243.90	39.18	191.90	332.50	0.46
3-Month Treasury Bill	3.09	4.15	2.16	0.04	5.34	-0.36
S&P 500 Index	4293.65	4328.87	324.43	3583.07	5088.80	0.01

Note: Calculated using the *tidyverse* package in R (Wickham et al., 2019).

**Table 3: Regression Estimates for Log Transformation**

	(1)	(2)	(3)	(4)
Intercept	-0.031 (0.024)	12.433 (13.598)	76.486** (32.637)	92.256*** (34.226)
log (Carbon Offsets Contracts Log)	1.007*** (0.014)	0.965*** (0.030)	0.864*** (0.047)	0.833*** (0.050)
log (Real Gross Domestic Product)		-1.249 (1.352)	-3.010 (2.241)	-2.960 (2.395)
Real Interest Rate		-0.095 (0.064)	-0.114 (0.080)	-0.027 (0.100)
3-Month Treasury Bill		0.041 (0.035)	-0.054 (0.059)	-0.137* (0.070)
Interest Rate		0.113 (0.088)	-0.113 (0.142)	-0.122 (0.156)
log (Futures Natural Gas Contracts)			0.012 (0.075)	0.010 (0.100)
log (Futures Crude Oil Contracts)			0.265 (0.287)	0.543 (0.382)
log (Green Bonds Performance)			-2.605** (1.013)	-3.421*** (1.152)
log (Paris-Aligned ESG+ Index)			0.963 (3.358)	-1.637 (3.523)
log (S&P 500 Index)			-21.647* (11.693)	-27.908** (11.885)
log (Carbon-Efficient Index)			22.166** (10.796)	31.481*** (11.407)
Final Energy Demand				-0.007 (0.004)
log (Commercial Electricity Prices)				1.097 (0.886)
log (Global Price of Energy Index)				-0.137 (0.233)
log (Global Econ. Policy Uncertainty Index)				-0.178 (0.168)
R <sup>2</sup>	0.976	0.978	0.980	0.981
Adj. R <sup>2</sup>	0.976	0.977	0.978	0.978
Num. obs.	130	130	130	130

Note: Standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 4: Regression Estimates for Log Difference Transformation**

	(1)	(2)	(3)
Intercept	-0.023 (0.016)	-0.026 (0.016)	-0.019 (0.018)
$\Delta \log(\text{Carbon Offsets Contracts Lag})$	0.016 (0.089)	-0.016 (0.089)	-0.022 (0.092)
$\Delta$ (Inflation rate)		-0.165 (0.179)	-0.213 (0.190)
$\Delta \log(\text{S\&P 500 Index})$		-11.166 (20.013)	-13.624 (20.432)
$\Delta \log(\text{Futures Natural Gas Contracts})$		0.194 (0.177)	0.134 (0.192)
$\Delta \log(\text{Futures Crude Oil Contracts})$		-0.229 (0.432)	-0.128 (0.470)
$\Delta \log(\text{Green Bonds Performance})$		-3.662** (1.783)	-3.623* (1.848)
$\Delta \log(\text{Paris-Aligned ESG+ Index})$		-9.562 (5.965)	-11.877* (6.292)
$\Delta \log(\text{Carbon Efficient Index})$		22.129 (18.967)	27.018 (19.568)
$\Delta \log(\text{Real Gross Domestic Product})$			-1.792 (4.276)
$\Delta$ (Real Interest Rate)			0.162 (0.143)
$\Delta$ (3-Month Treasury Bill)			-0.201 (0.159)
$\Delta$ (Final Energy Demand)			-0.214 (0.871)
$\Delta \log$ (Commercial Electricity Prices)			0.720 (1.735)
$\Delta \log$ (Global Price of Energy Index)			0.099 (0.406)
$\Delta \log$ (Global Econ. Policy Uncertainty Index)			-0.235 (0.243)
$R^2$	0.000	0.072	0.102
Adj. $R^2$	-0.008	0.010	-0.017
Num. obs.	129	129	129

Note: Standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$