INTERNATIONAL JOURNAL FOR INNOVATION EDUCATION AND RESEARCH
ISSN: 2411-2933

Journal URL: https://scholarsjournal.net/index.php/ijier

DOI: https://doi.org/10.31686/ijier.vol10.iss10.3912

An Analysis of Offset Emission Permit Pricing Factors in the Korean Carbon Market

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Abstract

This study aims to empirically analyze the long-run and short-run equilibrium relationship between the price of Korea Offset Unit (KOC) listed and traded on the Korean Exchange since May 2016, and the variables affecting it, such as Korea Allowance Unit (KAU) price, oil, electricity, economic survey prospect index of the general manufacturing business, heating index and cooling index. In general, research on emission permit prices is conducted on the demand side and the supply side. This study analyzes the relationship in the demand side, and weekly time series data for about 6 years from the end of May 2016 were used with the ARDL model. As a result of the empirical analysis, KOC showed a positive correlation between KAU and oil price, and showed a negative correlation with the prospect of Business Survey Index in the long run. In the short term, KAU, oil price, and electricity price showed a positive correlation, and the prospect of Business Survey Index showed a negative correlation.

Keywords: KOC; KAU; ARDL model; Emission Allowance; Korean Carbon market

1. Introduction

It is an undeniable fact that climate change caused by global warming is caused by human activities. According to the 6th report released in 2021 by the Intergovernmental Panel on Climate Change (IPCC), widespread and abrupt changes due to human activity have occurred in the atmosphere, oceans, cryosphere (polar and alpine glaciers) and biosphere. Among these human activities, the biggest influence on climate change is the emission of greenhouse gases including carbon dioxide, and the world has been carrying out various activities to reduce greenhouse gases since 1990. The most representative market policies for greenhouse gas reduction are the target management system that directly regulates the total amount of greenhouse gas emissions, the Emissions Trading Scheme (ETS) that allows transactions using a market mechanism after limiting the total amount of emissions, and a tax on emissions. carbon tax, etc. IPCC (2014) recommends introducing the carbon tax and carbon trading system to the international community because it is superior to direct control methods such as the target management system in terms of efficiency and equity.

In Korea, the Korea Emissions Trading Scheme (K-ETS), a carbon trading system, has been operating since January 2015. As shown in Table 1, the operation period is divided into three phases, and the first implementation year was operated for three years from 2015 to 2017 with the goal of gaining experience for the smooth operation of the carbon market. The second transition year aimed at expanding the market and stable operation based on the operating experience of the first transition year, and was operated for three years from 2018 to 2020. Currently, it belongs to the 3rd transition year, which aims to effectively reduce carbon emissions based on the operational experience of the 1st and 2nd transition years.

The carbon credits recognized in the domestic carbon market are largely divided into allocated credits and offset credits. Companies subject to allocation that comply with the K-ETS obligations are allocated the amount of emission permits in units of KAU (Korea Allowance Unit, 1KAU=1CO2eq.ton) corresponding to the quota previously determined by the government. Another method is to receive KOC (Korea Offset Unit), which is an external project emission right, when the companies subject to the allocation are recognized as an external project for their GHG reduction performance performed outside. If companies subject to allocation want to use KOC to comply with their obligations under K-ETS, they can convert it to KCU (Korea Credit Unit). The exchange rate is 1 KOC = 1 KCU = 1 KAU. Therefore, the Korean carbon credit market refers to the market in which KAU, KCU, and KOC are traded, and these are divided into an exchange market traded on the Korea Exchange and an over-the-counter market traded by a contract between the parties.

The domestic carbon credit system differs from the carbon credits of EU-ETS in several respects, such as the momentum system and the transition year system. The momentum system is a system that recognizes the final asking price as the closing price even though no transaction has occurred. The bid price, which is the upper limit compared to the previous day's base price, becomes the 'momentum upper limit', and on the contrary, the bid price that is the lower limit compared to the previous day's base price becomes the 'low momentum'. This system was introduced to compensate for the shortcomings in the market, where domestic emission permits are experiencing a liquidity shortage, where trading does not occur due to lack of sale on most trading days except for a specific period. However, since there are many cases where no transaction occurs, there is a disadvantage in that it is difficult to expect a signal effect of the price or guarantee the efficiency of the market.

Domestic carbon credits also have a fixed trading period for each item. Emissions permits within the emission implementation plan period are classified by year of implementation, and emission permits after the implementation year cannot be used for submission for obligatory fulfillment. The flexibility mechanism allows for borrowing as well as carry-over. For example, before the start of the second planning period, a company subject to allocation is allocated KAU 18, KAU 19 and KAU 20 and holds it in their trading account. However, even if a company subject to allocation has been allocated emission permits for each fulfillment year and holds it in their account, only KAU 18 and partially borrowed KAU 19 can be used when submitting emission permits for the fulfillment of obligations for 2018, and the remaining KAU 19 and KAU 20 cannot be submitted. Therefore, depending on the implementation year granted to the allowances, there is a difference in whether or not the obligations of the allowances can be fulfilled, which is expected to affect the price of the allowances in some way. This can be referred to as the term structure according to the year of implementation of emission permits.

Table 1. Operation of the emission trading system by planned period

	1st period ('15 - '17)	2nd period ('18 - '20)	3rd period ('21 - '25)
Main goal	Accumulation of experience and establishment of trading system	A significant reduction in greenhouse gas emissions	Active reduction of greenhouse gases
System operation	Improvement of system flexibility, such as the scope of offsetting recognition Establishment of infrastructure for accurate MRV execution	Expanding the scope of the trading system and raising the target Advancement of various standards such as emission reporting and verification	Inducing voluntary reduction in preparation for the new climate regime Expansion of liquidity supply, including participation in third-party trading systems
Allocation	Free allocation Utilize the experience of the goal management system	Start of paid allocation * Free: 97%, Paid: 3% Advancement of allocation methods such as benchmark allocation	Expansion of paid allocation ratio * Free: 90%, Paid: 10% Establishment of an advanced allocation method

- Reference: Korea Environment Corporation

KOC is a kind of offsetting allowances for external business certification pursuant to Article 30 of the “Act on Allocation and Transaction of Greenhouse Gas Emission Permits” in South Korea. In order to be recognized as an emission reduction performance, it must be converted into KCU and submitted. However, since listing on the Korea Exchange on May 23, 2016, exchange-traded trading has been possible, and as a result, KCU's trading volume has sharply decreased since 2018. In the first planning period, there was no limit to the submission limit of the proportion of offsetting allowances out of the amount of emissions allowed to companies subject to allocation, but it is gradually being reduced to 10% in the second planning period and 5% in the third planning period.

For the reasons described above, since KCU has rarely been actually traded since 2018, the reliability of the analysis is weak. Therefore, this paper analyzes the factors that determine the market price of KOC, which are closely related to KCU, the price of offsetting allowances in K-ETS. Section 2 reviews previous studies conducted at home and abroad, and presents an ARDL model suitable for the analysis of this study. Section 3 introduces data for analysis and provides basic statistics. Section 4 presents the results of the analysis, and section 5 summarizes the results of the study.

2. Literature review and models

2.1 literature review

The purpose of this study is to investigate the relationship between the KOC price, which is actually offsetting allowances, KAU, which is the carbon allowance, energy variables, economic variables, and temperature variables in the Korean carbon market. To achieve these research goals, we use the ARDL approach.

The main factors that determine the price of emission permits are energy variables, macroeconomic variables, temperature variables, and other variables (institutional factors, substitution product factors, trading volume, etc.). This study attempts to estimate the correlation by considering only energy variables, economic variables, temperature variables, and carbon credits among various factors that affect the price of offsetting credits. Also, since KOC is exchanged with KAU one-to-one, it affects the price of KOC. Although the two permits should be traded at the same price, the price difference inevitably exists because the trading volume, production method, and certification allowable range of the two permits show various differences in the carbon market.

From the company's point of view, energy price is regarded as a factor of production that can affect the profitability of the company, and the company will reduce the use of higher cost energy. In this context, the energy variable factor is expected to have the greatest influence in the offsetting credit pricing factor. When the energy price rises (falls), energy demand falls (rises), and the price of emission permits will fall (increase). According to previous studies on EU-ETS pricing such as Keppler and Mansandet-Bataller (2010), Aatola et al. (2013), and Zhu et al. (2019), the largest consumer of carbon credits is power generation companies, the price of carbon credits is closely related to the price of energy required to generate electricity. In previous studies on EU-ETS and K-ETS markets, petroleum, coal, electric power, and natural gas were used as energy variables. According to the purpose of the study, Dubai oil and Brant oil price and futures indices, coal and natural gas emission factors, power generation efficiency, and electricity spread were used as variables. According to a study by Yun (2017), natural gas, coal, and exchange rates with the US have a statistically significant effect on changes in the power system marginal price (SMP) of the electricity system. Thus, SMP and oil price (KO) were used as variables.

However, in the case of electricity wholesale price, the price fluctuates flexibly by SMP, but electricity retail price is almost fixed due to government regulation. They do not have the effect of reducing power consumption by reducing power generation companies' emissions. In this structure, the difference is expected to decrease with the introduction of the cost-linked electricity rate system in January 2021. Even after the introduction of the system, the temperature variable, rather than the energy factor, is the actual determining factor in the price of electricity. In this study, there is a possibility that energy factors and electricity prices do not affect the price of offsetting allowances in Korea.

A recession in the economy can reduce production and lead to a decrease in energy demand. As a result, carbon emissions will decrease and market demand for allowances will decrease, which will affect the price of offsetting allowances. In other words, all other conditions being equal, emission permit prices are expected to be pro-cyclical. In the previous study, macroeconomic variables such as economic growth rate, industrial production index, economic sentiment index, and FTSE350 index were used as variables. Hintermann (2010) analyzed that the stock market index had no significant effect on the emission permit price, but Creti (2012) showed that the stock market index was an important variable. As economic indicators in this study, the prospect of Business Survey Index(BSI) for general manufacturing and power generation industries were used to predict the future corporate economy.

Temperature and weather variables are related to energy use and can affect the price of allowances. This is because, when energy consumption for cooling and heating increases, carbon emissions and demand for emission permits increase. Hintermann (2010) explained that changes in temperature and weather affect electricity production and thus affect credit prices, but temperature variables were not significant in most studies. In the study of Hintermann (2010), climate-related variables were classified into cold months (November-March) and hot months (June-September) as dummy variables, and heating index and cooling index were used. In this study, heating index and cooling index were used as variables.

2.2 Model classification: ARDL model

To determine whether a long-term relationship exists between time series variables, Pesaran and Shin (1999) and Pesaran et al. (2001) uses the ARDL (Autoregressive Distributed Lag) model. To illustrate the ARDL modeling approach, the relationship between KOC and other explanatory variables can be expressed as

$$\mathrm{KOC_t} = \beta_0 + \beta_1\mathrm{KAU_t} + \beta_2\mathrm{KO_t} + \beta_3\mathrm{KEL_t} + \beta_4 KBSI_{idus_t} + \beta_5 KBSI_{elec_t} + \beta_6\mathrm{HDD_t} + \beta_7\mathrm{CDD_t} + u_t \qquad (1)$$

where u_t is the error term and the definitions of variables are as Table 2. For the ARDL-bounds test, the ARDL model can be expressed as the following unrestricted error correction model (UECM, or conditional ECM in Pesaran et al. (2001)).

$$\Delta\mathrm{KOC_t} = \alpha_0 + \sum_{k_1=1}\alpha_{1k_1}\Delta\mathrm{KOC}_{\mathrm{t}-k_1} + \sum_{k_2=1}\alpha_{2k_2}\Delta\mathrm{KAU}_{\mathrm{t}-k_2} + \sum_{k_3=0}\alpha_{3k_3}\Delta\mathrm{KO}_{\mathrm{t}-k_3} + \sum_{k_4=0}\alpha_{4k_4}\Delta\mathrm{KEL}_{\mathrm{t}-k_4} + \sum_{k_5=0}\alpha_{5k_5}\Delta KBSI_{idus_{\mathrm{t}-k_5}} + \sum_{k_6=0}\alpha_{6k_6}\Delta KBSI_{elec_{\mathrm{t}-k_6}} + \sum_{k_7=0}\alpha_{7k_7}\Delta\mathrm{HDD}_{\mathrm{t}-k_7} + \sum_{k_8=0}\alpha_{8k_8}\Delta\mathrm{CDD}_{\mathrm{t}-k_8} + \alpha_9\mathrm{KAU_{t-1}} + \alpha_{10}\mathrm{KO_{t-1}} + \alpha_{11}\mathrm{KEL_{t-1}} + \alpha_{12}KBSI_{idus_{t-1}} + \alpha_{13}KBSI_{elec_{t-1}} + \alpha_{14}\mathrm{HDD_{t-1}} + \alpha_{15}\mathrm{CDD_{t-1}} + \varepsilon_t \qquad (2)$$

Here, Δ is the difference operator and ε_t is the error term. Information criteria such as AIC and BIC are used to determine the disparity used in the model. Using the estimated ARDL model, the ARDL-bounds test is performed to analyze whether the cointegration relationship between variables is established and the dynamic relationship between long and short periods.

The ARDL approach has the following advantages over the existing cointegration test method. First, it can be analyzed using I(0) or I(1) data, and it is possible to test with consistency even when you do not know whether each variable is I(0) or I(1). Second, the ARDL approach is simple because it uses a single equation to solve. Third, different lag lengths for each variable can be used in the model. It also provides an unbiased estimate of long-run relationships. Finally, the endogeneity problem can be alleviated using self-lag distribution variables (Harris and Sollis, 2005).

3. Data

Since the KOC to be analyzed in this study was listed on May 23, 2016, the analysis period will be approximately 6 years from then to June 22, 2022. In general, the weekly closing price was used based on the Friday closing price, and if there was no Friday data, the data on Thursday the day before or the Monday of the following week was used. In order to comply with carbon reduction obligations, companies subject to allocation of carbon credits generally submit KAU, which is the allocation of credits, first and then submit the shortfall to KOC, so the price of KAU is naturally included in the price determining factor of KOC. However, since KAU is a product that expires every transition year, some manipulation is required to become a factor in a product with price continuity until recently, like KOC. In this study, KAU, which is an explanatory variable for KOC, was created by combining only the KAU price of the most recent KAU, considering that KAU products with the most recent maturity from KAU16 to KAU21, each of KAU vintages, have the most liquidity.

In addition to this, this study examines oil price (KO) as an energy index, electricity price as an economic index, the prospect of the general manufacturing business survey index (KBSI_idus), the prospect of the power generation business survey index (KBSI_elec), the heating index (HDD) as a temperature index, Daily time-series data of the cooling capacity (CDD) were used as explanatory variables. The definitions of variables used in this study are as follows.

Table 2 Definitions of variables

	Variables	Short cut of variables	Note
Dependent variable	KOC (weekly closing price)	KOC	2016.05.27-2022.06.17
Explanatory variable	KAU with the most recent maturity (weekly closing price)	KAU	2016.05.27-2022.06.17
	Oil price	KO	International Dubai oil prices
	Electricity price	KEL	Electricity System Marginal Price(SMP)
	the prospect of general manufacturing business survey index	$KBSI_{idus}$	Large corporations and SMEs manufacturing
	the prospect of the general manufacturing business survey index	$KBSI_{elec}$	Electricity, Gas, Steam
	the heating index	HDD	Based on Seoul area
	the cooling capacity	CDD	

For the emission permit price (KAU16-KAU21), the weekly closing price of the most recent maturity among

KAU16, KAU17, KAU18, KAU19, KAU20, and KAU21 traded on the Korea Exchange (KRX: krx.co.kr) was used. For the oil price (KO), since Bunker-C oil is mainly used in industries and conversion sectors including companies subject to allocation, the Bunker-C price (KRW/ℓ) provided by Korea National Oil Corporation was used instead of the international crude oil price. The electricity price (KEL) is provided by the electricity statistics information system of the Korea Electric Power Exchange, and the business survey index ($KBSI_{idus}$, $KBSI_{elec}$) is based on the data provided by the Bank of Korea economic statistics system. The prospect index was estimated by weighting it based on the production amount[1]. Temperature variables (HDD, CDD)[2] were estimated using data from the highest and lowest temperatures, and the data for this study are weekly data from May 23, 2016 to June 22, 2022.

4. Empirical Results

4.1 Basic statistics

Variables were weekly data from May 27, 2016 to June 17, 2016, and 317 data were used for each variable. The basic statistics of the variables are as Table 3.

Table 3 Basic statistics

Variables	Mean	St. dev.	Median	Max	Min	Coefficient of variation
KOC	26897	6600.50	25000	40800	17000	0.25
KAU	24592	6648.46	22350	40800	7880	0.27
KO	61.47	17.46	60.94	127.86	17.97	0.28
KEL	92.87	30.01	84.65	212.86	49.99	0.32
KBSI_elec	84.92	9.52	87.00	112.00	63.00	0.11
KBSI_idus	77.62	10.37	77.00	99.00	49.00	0.13
HDD	6.89	8.20	3.00	32.65	0.00	1.19
CDD	2.64	3.88	0.00	15.95	0.00	1.47

4.2 Unit root test

The ARDL-bounds test proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) to check the cointegration relationship in the Auto Regressive Distributed Lag (ARDL) approach can be used when time series data follow I(1). Compared to the Vector Error Correction Model (VECM), it can be used for partially integrated time series in which variables follow 0≤d≤1. If a variable is integrated with I(2) or higher, the

[1] Based on 2019 production amount, 64% of large enterprises, 36% of small and medium-sized enterprises (Ministry of SMEs and Startups, 2019)

[2] The Heating degree days index (HDD) and Cooling degree days index (CDD) are the most actively used indices in weather derivative trading. The calculation is following. (Bae and Choung, 2009)

$$\mathrm{HDD} = \mathrm{Max}(18℃ - T_i, 0), CDD = \mathrm{Max}(T_i - 18℃, 0)$$

$$\mathrm{T_i} = \frac{\mathrm{T_{max}} - \mathrm{T_{min}}}{2}, \mathrm{T_{max}} = \text{Daily maximum temperature}, \mathrm{T_{min}} = \text{Daily minimum temperature}$$

ARDL-bounds test cannot be performed. Therefore, before performing the ARDL-bounds test, a unit root test is performed to confirm the stationarity of each economic variable in the model.

In this study, the ADF test (Augmented Dickey-Fuller Test) is implemented as a method for unit root test.

Table 4 Time series stability

variables	Level (ADF)		1st difference (ADF)		Stability
	Coefficient	p-value	Coefficient	p-value	
KOC	-3.1782	0.0919	-5.7144	≤0.01(***)	I(1)
KAU	-2.2186	0.4843	-6.4368	≤0.01(***)	I(1)
KO	-2.9376	0.1811	-6.5536	≤0.01(***)	I(1)
KEL	-2.1551	0.5111	-8.2127	≤0.01(***)	I(1)
KBSI_elec	-2.3657	0.4222	-7.0564	≤0.01(***)	I(1)
KBSI_idus	-2.0205	0.5678	-6.5555	≤0.01(***)	I(1)
HDD	-4.9324	≤0.01(***)	-4.5905	≤0.01(***)	I(0))
CDD	-5.2749	≤0.01(***)	-5.4832	≤0.01(***)	I(0)

As a result of the ARDL-bounds test, at the 5% level, the lower threshold of I(0) is 2.27 and the upper threshold of I(1) is 3.28. The F-statistics of this ARDL model was 93.22, which showed that the cointegration relationship between variables was established.

4.3 ARDL long-run coefficient estimation

Estimated long-run relationship coefficients for KOC are as Table 5. It was confirmed that the price of KOC was statistically significant at the 1% level for the KAU price and the power generation industry survey index, and it was confirmed that it was statistically significant at the 10% level with the oil price, the general manufacturing industry survey index, and the heating index. This suggests that KOC has a strong character as a substitute for the domestic carbon credits KAU, is strongly influenced by the economic forecast of the power generation industry, and is also weakly affected by the oil price, KBSI_idus and the heating index. In particular, there was a positive (+) relationship between KAU and oil price, which is natural as a substitute for KAU, and it can be expected that the price of KOC will also rise if the price of oil rises due to increased demand for oil. KBSI_idus showed a very significant negative (-) relationship. If KBSI_idus is positive, energy demand increases and energy price rises, and demand decreases, resulting in a decrease in the demand for KAU and KOC. This leads to a fall in the price of KOC. There was a negative relationship with the heating index, which also increases energy demand, which seems to lower the price of KOC.

Table 5. Estimated long-run coefficients of the K-ETS carbon price.

variable	Coefficient	t-value
KAU	0.7927***	20.854
KO	44.11*	1.866
KEL	0.4617	0.038
KBSI_elec	-182.6***	-5.541
KBSI_idus	-64.22*	-1.965
HDD	-55.21*	-1.656
CDD	14.78	0.216
C	2.548***	11.003

Note : * indicates significantce at 10% level, ** at 5% level, *** at 1% level.

4.4 ARDL short-term coefficient estimation

Table 6. Estimated short-run coefficients of the K-ETS carbon price

	Coefficient	t-value
D(KOC(-1))	-0.0535	0.935
D(KAU)	0.1491***	4.657
D(KAU(-1))	-0.0122	-0.401
D(KAU(-2))	-0.0514*	-1.734
D(KAU(-3))	-0.0350	-1.163
D(KAU(-4))	-0.0175	-0.586
D(KO)	19.07	1.250
D(KO(-1))	31.96**	2.100
D(KEL)	6.717	0.817
D(KEL(-1))	14.07*	1.745
D(KEL(-2))	29.89***	3.734
D(KBSI_elec)	-13.61	-0.746
D(KBSI_idus)	-11.39	-0.491
D(KBSI_idus(-1))	-45.89**	-2.058
D(HDD)	8.050	0.663
ECT(-1)	-0.0015***	-4.215
C	1410**	2.253

Note : * indicates significantce at 10% level, ** at 5% level, *** at 1% level.

Table 6 shows the estimated short-run relationship for KOC. Short-run relationships also showed different results depending on factors. As expected, the KAU price shows a very significant positive short-run relationship with the KOC price. In the case of energy price, oil price was statistically significant at 5% level after 1 lag and electricity price after 2 lag and showed a positive (+) correlation as in the long-run relationship. The industry outlook index did not show a significant short-term relationship with the power generation industry but showed a statistically significant negative correlation with the general industry at 5% level after 1 lag. The residual estimated from Equation (1) was used as an error correction term in Equation (2). Through this result, the coefficient of the error correction term had a statistically significant negative sign at the 1% level, which means that the KOC price is in a long-run equilibrium relationship by about 0.15% through the short-run adjustment process in the next period regardless of the impact of any variable. This means that adjustments will be made.

5. Conclusion

This study empirically analyzed the long-run and short-run correlations in the demand side of the KOC price, which is an offsetting allowance, in the Korean carbon market. In the long-run relationship, KAU and oil prices showed a statistically significant positive correlation at the 10% level, and a statistically significant negative correlation with the economic survey index forecast at the 10% level. In the short-run, KOC showed a positive correlation with KAU and oil price, and electricity price showed a positive correlation with time lag in the short-run correlation, unlike the long-run correlation. It showed a negative correlation with the prospect of the general sector BSI. In addition, it was confirmed that the KOC price gradually adjusts to a long-run equilibrium relationship through the short-run adjustment process.

As KOC is an alternative to KAU, each company trades offsetting credits according to its carbon credits and emissions, and the results of this study can be used as a reference for future market forecasts.

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