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ENVIRONMENTAL EXTERNALITY VALUATION:

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ABSTRACT

Environmental policy regulating the greenhouse gas emissions of public companies is likely to become more prevalent in the coming years. Therefore, it is essential for public companies and investors alike to understand how the implementation of environmental policy will affect the valuation of public companies moving forward. Such an understanding improves decision-making and capital allocation planning from both a company and investor perspective. This study analyzes the financial materiality of greenhouse gas emissions in relation to environmental regulations passed in South Korea by performing a regression analysis of total or estimated greenhouse gas emissions, scaled by sales to allow for comparability across firms of different sizes, and the market valuation of South Korean Public companies. I find that emissions become financially material only after official emission allocations for public companies are set by the South Korean Government.

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INTRODUCTION

Arthur C. Pigou is an essential contributor to the development of externality theory. In his work, The Economics of Welfare (1932), Pigou introduces the idea that externalities occur when there is a divergence between the marginal private net product and the marginal social net product, where the marginal private net product is “that part of the total net product of physical things or objective services due to the marginal increment of resources in any given use or place which accrues in the first instance—i.e. prior to sale—to the person responsible for investing resources there” (p.79). The marginal social net product is “the total net product of physical things or objective services due to the marginal increment of resources in any given use or place, no matter to whom any part of this product may accrue” (p. 79) For any activity, the marginal social net product may be greater than, lesser than, or equal to the marginal private net product. Today, it is common to refer to the phenomenon of when the marginal social net product exceeds the marginal private net product as a positive externality, being beneficial to society, whereas when the marginal social net product is lesser than the marginal private net product is often referred to as a negative externality, being detrimental to society. When the marginal social net product is equal to the marginal private net product, the activity may be termed socially efficient.

Pigou provides hypothetical examples of both positive and negative externalities. It is clear that externalities relating to the environment were conspicuous for Pigou and have remained critical areas of study for economists today. For example, Pigou identifies parks as potential positive environmental externalities, saying, “uncompensated services are rendered when resources are invested in private parks in cities; for these, even though the public is not admitted to them, improve the air of the neighbourhood” (p. 107). On the other hand, he lists local air pollution as an important example of a negative environmental externality, saying, “smoke in large towns inflicts a heavy uncharged loss on the community, in injury to buildings and vegetables, expenses for washing clothes and cleaning rooms, expenses for the provision of extra artificial light, and in many other ways” (p. 107).

Perhaps the most widely recognized negative environmental externality is the emission of carbon dioxide (CO_2) and other greenhouse gases (e.g., CH_4, N_2O, fluorinated gases). Greenhouse gases and water vapor suspended in the earth’s atmosphere cause the greenhouse effect. First discovered by Joseph Fourier (1824) and Claude Pouillet (1838) in the 19^{th} century and later developed by John Tyndall (1860) and modern scientists, the greenhouse effect occurs when sunlight passes through the gases and heats the earth, which heat is subsequently radiated back by the earth as infrared radiation but is ultimately absorbed the same gases in the atmosphere, trapping the heat and increasing global temperatures. The greenhouse effect is a natural phenomenon, but the human-caused increase in greenhouse gases in the atmosphere has exacerbated its effect, causing global temperatures to rise.

The Intergovernmental Panel on Climate Change (IPCC), a scientific body of the United Nations, has cautioned that “climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5º C and increase further with 2º C" (Masson-Delmotte, et al., p. 11). The Panel also shows that "in model pathways with no or limited overshoot of 1.5º C, global net anthropogenic CO2 emissions decline by about 45% from 2010 levels by 2030 (40-60% interquartile range), reaching net zero around 2050 (2045-2055 interquartile range). For limiting global warming to below 2º C, CO2 emissions are projected to decline by about 25% by 2030 in most pathways (10-80% interquartile range) and reach net zero around 2070 (2065-2080 interquartile range)" (p. 14). In essence, global temperature increase poses a significant threat to humans, and a large-scale reduction in CO2 emissions is needed to prevent this from happening. It is important to note that CO2 emissions and greenhouse gas (GHG) emissions are often used synonymously. GHG emissions are often measured relative to CO2 in many cases. So, greenhouse gases such as C02, CH4, or N2O may all be measured in metric tons of CO2.

Corporations are significant emitters of greenhouse gases. For example, a 2017 report released by Carbon Majors found that "100 active fossil fuel producers are linked to 71% of global industrial greenhouse gases (GHGs) since 1988" (Griffin D. P., 2017 p. 8). As a result, several nations have implemented legislation and regulations in recent years to slow or reduce the amount of GHGs emitted in their countries, and much of that legislation targets corporations directly. According to a database maintained by the Grantham Research Institute on Climate Change and the Environment and the Sabin Center on Climate Change law, there are now more than 1,872 climate laws across 198 countries (Setzer & Byrnes, 2020).

There are various policy approaches employed to correct negative externalities. Broadly speaking, these approaches can be categorized into market-based policies, regulatory policies, and voluntary policies. Market-based policies, also referred to as emissions pricing policies include carbon taxes and emissions caps. A carbon tax sets a price on each unit of carbon emissions and introduces a tax on emitting entities for each unit of carbon emitted at the set price per unit. This price is ideally equal to the difference in the value of the marginal private net product and the marginal social net product, thus achieving social efficiency and eliminating the externality. According to the World Bank's Carbon Pricing Dashboard as of November 1, 2020, there are currently 32 carbon taxes in place spanning 25 countries and covering 5.6% of global greenhouse gas emissions (The World Bank, 2020).

An emissions cap, also referred to as a cap-and-trade (CAT) or emissions trading scheme (ETS), sets a cap on a maximum quantity of emissions rather than a set price per emission. The governing body issues tradeable permits authorizing an entity to release a set amount of carbon emissions. Entities that produce fewer emissions than their maximum emissions level may sell their permits to entities producing more emissions than their maximum emissions level, allowing both entities to remain compliant with their maximum emission quantity. Thus, a market for tradeable permits of carbon emissions is created and, as such, allows supply and demand to a market price per unit of emissions. In some cases, a price floor or price ceiling per unit of emissions may be introduced to regulate the market price. According to the World Bank's Carbon Pricing

Dashboard as of November 1, 2020, there are currently 31 emission trading schemes in place spanning 39 countries and covering 17.0% of global greenhouse gas emissions (The World Bank, 2020).

Regulatory policies include technology standards and efficiency regulations. For example, a governing body may require entities to utilize a particular, low-emission technology or process or restrict an entity from using a high-emission technology or process. Voluntary policies include subsidies and credits. Governing bodies may directly subsidize technologies that promote fewer emissions than existing technologies, improve their competitiveness, and increase the likelihood of replacing existing technology. Examples of this approach include the United States' Investment Tax Credit (ITC) and Renewable Electricity Production Tax Credit (PTC) which incentivize the use of clean energy.

Despite increased usage of climate policy, additional legislation will be required to achieve global climate goals such as, for example, the Paris Agreement. Therefore, it will become increasingly important to understand what effects climate policy has on corporations, their investors, and other relevant stakeholders. The relationships between corporate greenhouse gas emissions, public equity valuations, and national climate policy are the subject of this study and have been the subject of several adjacent studies. Most existing research has shown a statistically significant relationship between greenhouse gas emissions and stock valuations or stock returns, where higher emissions result in lower stock valuations and higher stock returns, implying that investors require a higher return for the increased risk of holding a company with significant emissions.

Some research has also been performed that studies how the relationship between greenhouse gas emissions and stock valuations changes due to emissions regulation. This study contributes to that research by performing such an analysis in South Korea. I use regression analyses of greenhouse gas emissions and stock price multiples for South Korean public companies at different time periods that correspond to the implementation of legislation that contributed to the creation of the South Korean Emissions Trading Scheme (K-ETS).

I find that the only statistically significant relationship between greenhouse gas emissions and stock valuations occurs after December 3, 2014, the date that greenhouse gas emissions are officially set. After the launch of the K-ETS on January 1, 2015, however, the relationship once again fails to achieve statistical significance. This study will be of use to public companies and investors alike, especially those operating or investing in countries with impending climate legislation, such as China.

While further research is needed to confirm the results presented here, an investor may utilize these results to make investment decisions based on greenhouse gas emissions by a public company. For example, an investor may disregard the risk factor of greenhouse gas emissions in the time period after an emissions pricing scheme is proposed but before official allocations are set. Before the release of official allocations, an investor may decide to restructure their portfolio by incorporating firm-specific emission risk into their models, as I have shown that greenhouse gas emissions will likely affect a company's valuation during the time period immediately following the release of official emission allocations by a governing body.

METHODOLOGY

A regression analysis is performed to identify the relationship between a public company's greenhouse gas emissions and its stock valuation. The South Korean Emissions Trading Scheme (K-ETS) is used due to its large size and recent implementation date of January 1, 2015. As of November 1, 2020, the South Korean Emissions Trading Scheme (K-ETS) is the 3rd largest in the world in terms of greenhouse gas emissions covered at 489 $MtCO_2e$, second only to the China national ETS and the EU ETS, and trades nearly $18 billion of emissions on the exchange.

All data is sourced from Bloomberg Inc. Several elements utilized by Freiberg et al. (2020) are implemented in this study. Namely, a regression analysis is performed between companies' greenhouse gas emissions and its market valuation. Bloomberg's Total Greenhouse Gas and CO_2 Emissions Per Sales data point is used, which is a total measure of a company's greenhouse gas emissions and CO_2 emissions divided by the organization's annual sales to make emissions comparable across firms of different sizes. Total Greenhouse Gas and CO_2 Emissions Per Sales is referred to as Emission Intensity in this study to match terminology used by Bloomberg. Not all companies included in the data set report emissions during the time periods USD in the study. To adjust for selection bias where only companies reporting are assessed, Bloomberg's Estimated Total Greenhouse Gas and CO_2 Per Sales (Estimated Emission Intensity) data point is used to impute missing values, which uses industry average emissions to estimate greenhouse gas emissions for each company. Emission intensity is regressed against a company's stock valuation, which, similar to the methodology used by Freiberg et. al. (2020), is measured using price-to-book value. To explain the relationship between all public companies' valuation and greenhouse gas emissions, the entire universe of South Korean Public companies is used for each time period. Therefore, the dataset changes over time as companies are added or subtracted from this universe. The dataset also changes over time as companies begin to report their greenhouse gas emissions in public filings. For example, a company may not report emissions in the first time period but does report emissions in each time period after the first time period. In such a case, Bloomberg's Estimated Emission Intensity data point is used to impute values for the company during the first time period, while the company's actual Emission Intensity is used in every period thereafter. The proportion of companies reporting greenhouse gas emissions increases over time, with later periods containing a higher proportion of companies reporting their emissions than early periods.

The regression analysis is performed on the day before, the day of, and the day after several critical dates in the timeline of the formation of the K-ETS, using information from South Korea's Office for Government Policy Coordination to identify key dates. Those dates and a description of their relevancy is included below:

- January 13, 2010 – Framework Act on Low Carbon Green Growth sets the legal basis for an Emissions Trading Scheme
- May 14, 2012 – Act on the Allocation and Trading of Greenhouse Gas Emission Permits passed, setting national emissions caps
- January 28, 2014 – 2nd Basic Energy Plan passed that sets long term targets for emissions reduction via K-ETS
- March 18, 2014 – 2nd Basic Energy Plan signed into law
- December 3, 2014 – Emissions allocations set for Phase I of the National Allowances plan (2015-2017)
- January 1, 2015 – K-ETS officially launches

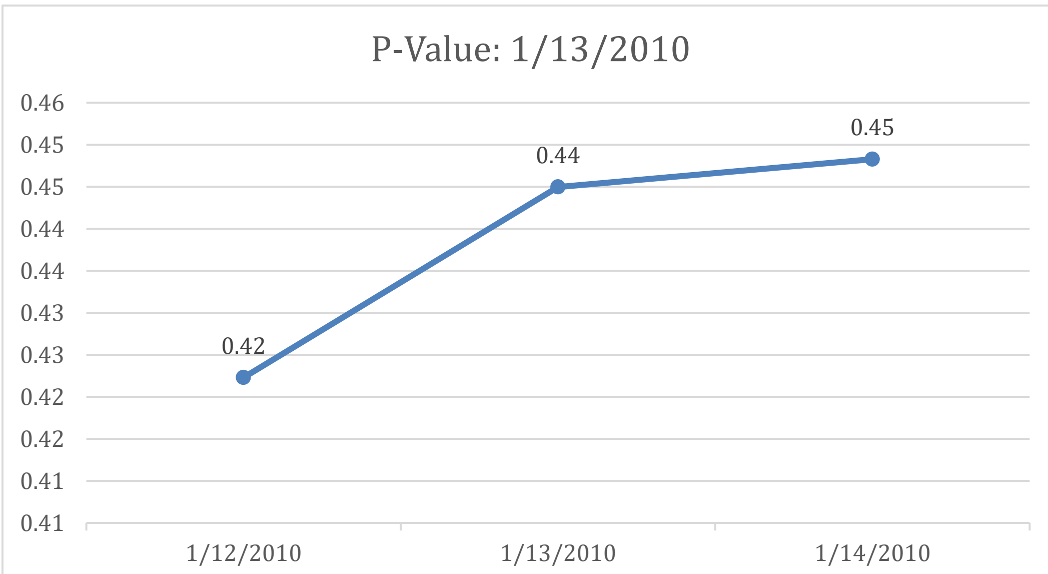
An additional regression analysis is performed at the beginning of each year from 2010 to 2016 to track the relationship between greenhouse gas emissions and stock valuations over time. Using a confidence level of 95%, each regression analysis demonstrates whether the relationship is statistically significant or not and whether or not the statistical significance changes after the given climate policy is implemented. Only regression analyses with p-values lower than 0.05 are assumed to be statistically significant, where statistical significance suggests a meaningful relationship between greenhouse gas emissions and company valuation.

RESULTS

The statistical significance of the relationship between greenhouse gas emissions and stock valuation at each time period is shown below. See the Appendix for regression outputs for each time period.

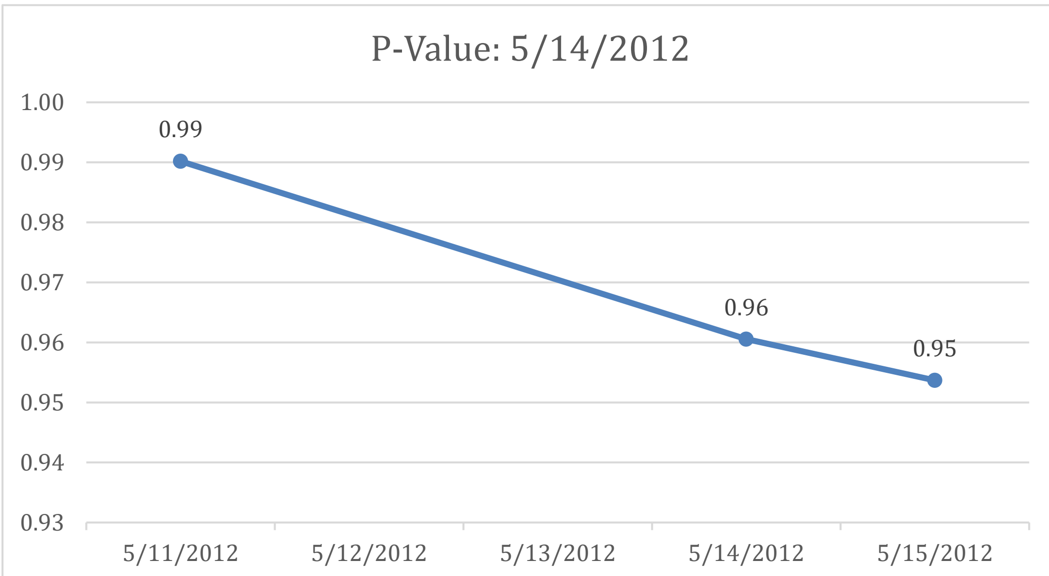
January 13, 2010 – Framework Act on Low Carbon Green Growth sets the legal basis for an Emissions Trading Scheme

There is no demonstrated financial materiality between emissions and stock valuation on the day before the signing of the Framework Act, the day of the signing of the Framework Act, or the day after the signing of the Framework act. It is therefore suggested that investors are not incorporating greenhouse gas emissions as a material risk factor in the valuation of South Korean public companies and that the passage of this policy had no effect on the financial materiality of greenhouse gas emissions.



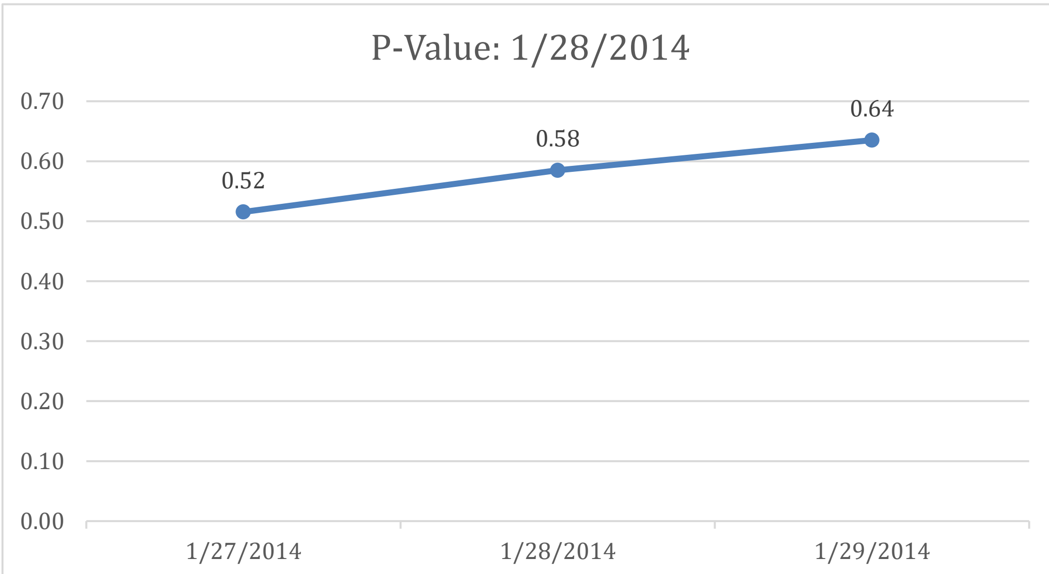
May 14, 2012 – Act on the Allocation and Trading of Greenhouse Gas Emission Permits passed, setting national emissions caps

There is no demonstrated financial materiality between emissions and stock valuation on the day before the signing of the Act on the Allocation and Trading of Greenhouse Gas Emission Permits, the day of the signing, or the day after the signing. It is therefore suggested that investors are not incorporating greenhouse gas emissions as a material risk factor in the valuation of South Korean public companies and that the passage of this policy had no effect on the financial materiality of greenhouse gas emissions.



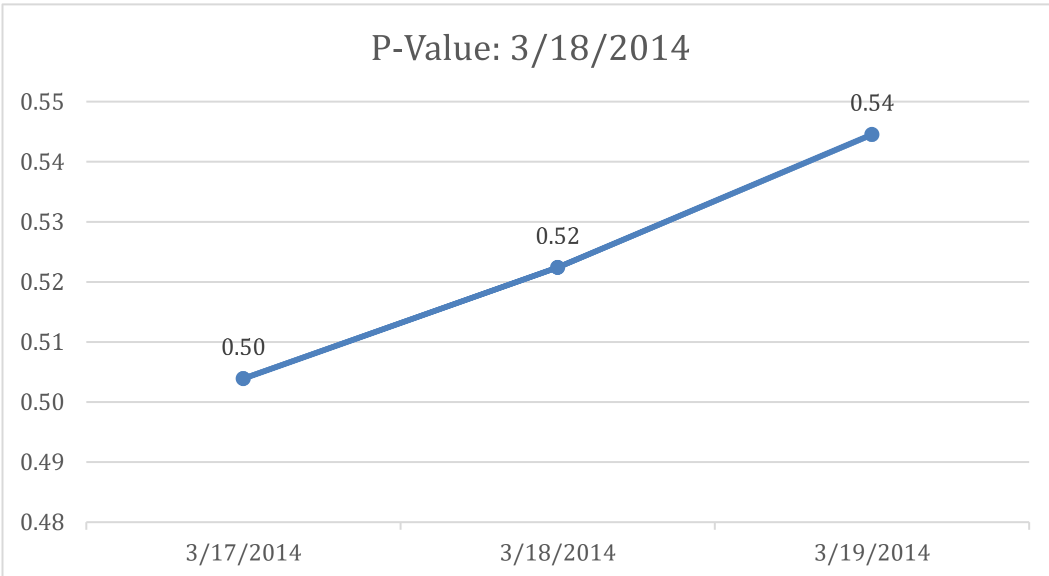
January 28, 2014 – 2nd Basic Energy Plan passed that sets long term targets for emissions reduction via K-ETS

There is no demonstrated financial materiality between emissions and stock valuation on the day before the passage of the 2nd Basic Energy Plan, the day of its passage, or the day after its passage. It is therefore suggested that investors are not incorporating greenhouse gas emissions as a material risk factor in the valuation of South Korean public companies and that the passage of this policy had no effect on the financial materiality of greenhouse gas emissions.



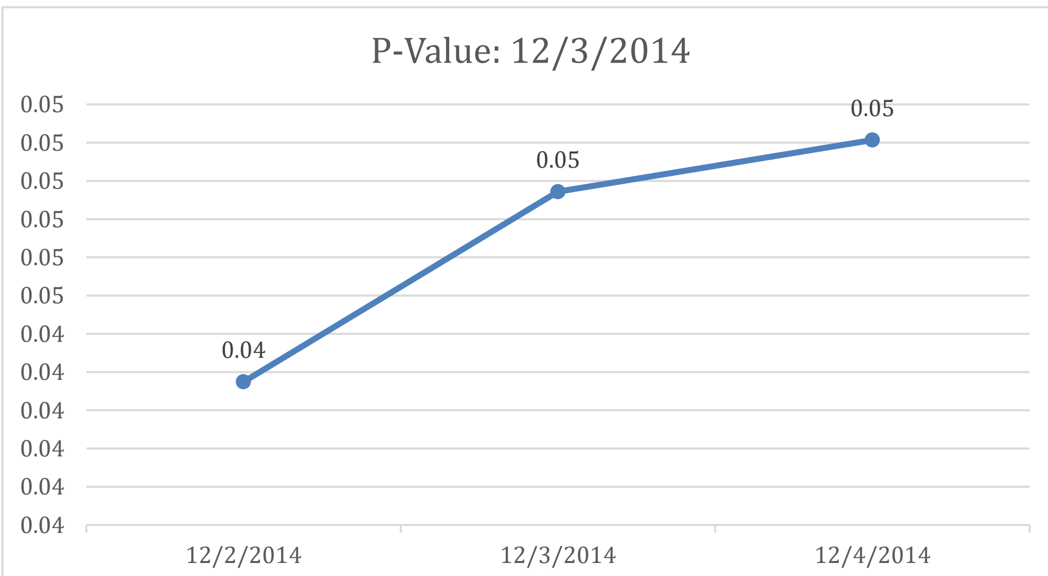
March 18, 2014 – 2nd Basic Energy Plan signed into law

There is no demonstrated financial materiality between emissions and stock valuation on the day before the official signing of the 2nd Basic Energy Plan, the day of its signing, or the day after its signing. It is therefore suggested that investors are not incorporating greenhouse gas emissions as a material risk factor in the valuation of South Korean public companies and that the passage of this policy had no effect on the financial materiality of greenhouse gas emissions.



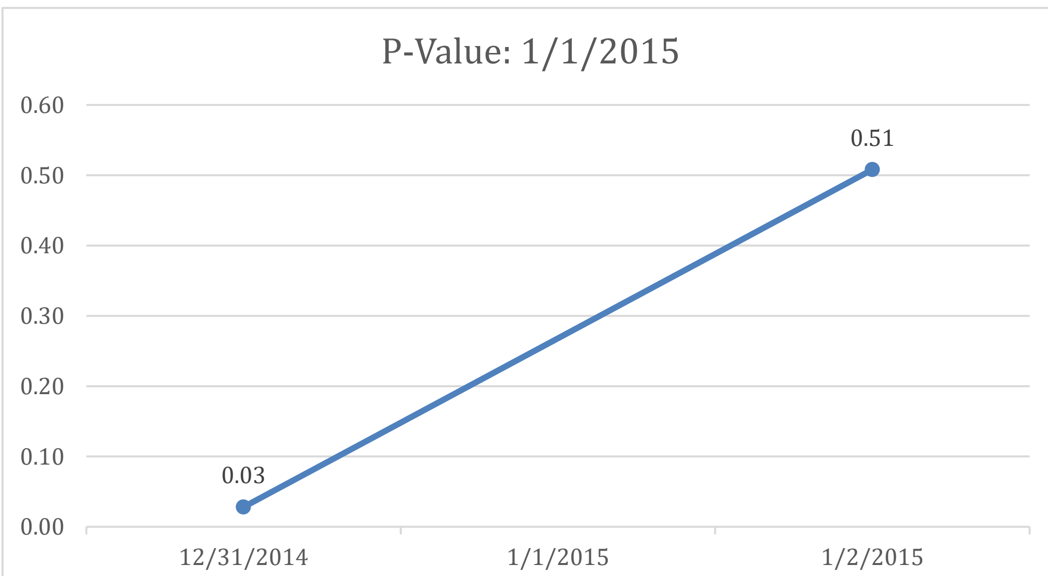
December 3, 2014 – Emissions allocations set for Phase I of the National Allowances plan (2015-2017)

The release of official emission allocations for the K-ETS is the only time period that demonstrates a statistical significance in the relationship between greenhouse gas emissions and stock valuations. Interestingly, the relationship is strongest on the day before the release of official allocation limits and decreases very slightly on the day of the release and the day after release. This illustrates something of an anticipatory effect from investors. That is, investors anticipate that the release of emission allocations will make greenhouse gas emissions a material risk factor for each company before emission allocations are set. Seeing the financial materiality relationship decrease only slightly in the days following the allocations release confirms that as a result of emission allocations released by the South Korean government, investors now view greenhouse gas emissions as a statistically significant factor in the valuation of a public company in South Korea.



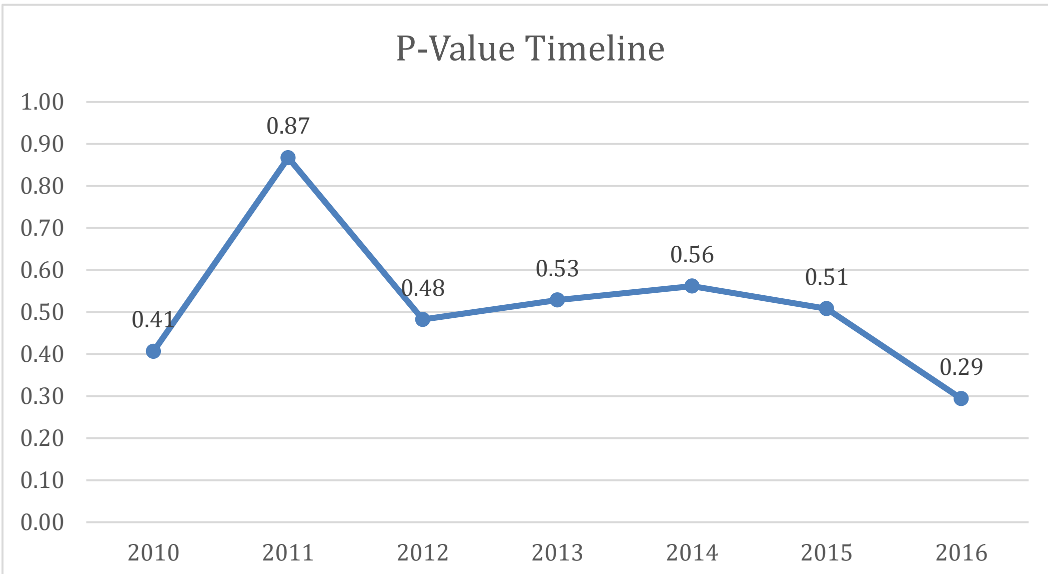
January 1, 2015 – K-ETS officially launches

Only the date preceding and immediately following the official launch of the K-ETS is used as the launch date is a market holiday. December 31, 2014, the date immediately preceding the official launch of the K-ETS, shows the strongest relationship between greenhouse gas emissions and stock valuations of all time periods evaluated. This suggests that even before the K-ETS has officially launched, investors believe that greenhouse gas emissions are financially material to the value of a public company in South Korea. On January 2, 2015, the relationship between emissions and stock valuations once again fails to achieve statistical significance. While it is possible that this suggests an over-exaggeration of financial materiality in the days preceding the launch, it is more likely that this relationship has become skewed by the addition of new data to the dataset. On January 2, 2015, new emission data were reported by several companies, and several companies are added to the public market in South Korea. Therefore, the data on January 2, 2015, is not directly comparable to the data on December 31, 2014.



Significance Timeline from 2010 to 2016

There is no statistically significant relationship observed at the time periods studied from 2010 to 2016. Only the first day of the year for each time period in the timeline was used to determine statistical significance. As a result, the data provided may include a seasonality bias that clouds the relationship between emissions and stock valuations. For example, it is possible that a large number of companies report their emissions later in the year. So, while there is no statistically significant relationship as of the first day of the year, the relationship may become statistically significant later on. In the future, a timeline analysis should include data points from each market day of the year to compensate for any potential seasonality bias in the data.



DISCUSSION

The results indicate a statistically significant relationship between a company's greenhouse gas emissions, scaled by sales to provide for comparability, and its stock valuation. In other words, investors view greenhouse gas emissions as financially material to a South Korean public company's value. This is consistent with existing research. However, the results provided here identify that a statistically significant relationship is not always present, a slight divergence from existing research.

The results of the regression analyses performed show that out of each time period analyzed, only the time periods immediately preceding or immediately following the official allocation of emissions by the South Korean Government showed a statistically significant relationship between greenhouse gas emissions and stock valuations. This suggests that investors do not view greenhouse gas emissions as financially material until the scale of firm-specific emission reductions required by official emission allocation plans becomes clear. In other words, greenhouse gas emissions are only financially material factors of a stock's valuation when investors become aware of the extent that a company must reduce or pay for its greenhouse gas emissions.

This lagging effect of the financial materiality of greenhouse gas emissions from the initial proposal of an emission trading scheme to its final implementation has important implications for investment strategies in public companies. If greenhouse gas emissions do not become financially material until official allocations are set, investors receive no benefit or penalty for holding a company with relatively high or relatively low greenhouse gas emissions, all else equal. This suggests that investment strategies that call for divestment of companies with significant greenhouse gas emissions only add value if the implementation of an emission trading scheme and official release of emission allocations are imminent. On the other hand, investors who incorporate greenhouse gas emissions into stock valuations and investment decisions before official allocations are set may receive a relative benefit by avoiding negative valuation effects caused when official allocations are set, and greenhouse gas emissions become financially material.

Analyzing the regression analyses from January 1, 2010, to January 1, 2016, shows that, with several exceptions, the relationship between greenhouse gas emissions and stock valuation has become more significant over time, although none of the time periods demonstrated statistical significance. This is consistent with existing research, such as the results found in Freiberg et al. (2020), who found a modest yet significant relationship between emissions and stock valuations that increased over time. However, given the relative unpredictability in the significance at each time period included in this timeline, the increase in significance does not follow a regular or linear pattern, seen in the graph above. Therefore, it is impossible to conclude whether the significance of the emissions-valuation relationship will continue to increase in the coming years or whether it will achieve or sustain statistical significance.

It is important to note that there are several limitations to this study. First, only a small percentage of emissions data used is actually reported by companies. The remainder of the data are imputed values using Bloomberg's estimated emission intensity data point. Thus, the actual emissions released by companies utilized in the data set may be significantly higher or lower than the estimated data. Because the dataset changes at each period to reflect the addition and subtraction of companies in the South Korean public company universe and as the proportion of companies reporting their emissions increases over time, the dataset may be more or less accurate in describing the relationship between greenhouse gas emissions and stock valuation at different time periods. Second, the number of events utilized in the study represents only a small portion of potentially financially material events relative to the valuation of carbon emissions. For example, during the time period utilized in the study, there were several ongoing lawsuits challenging the legal basis of the K-ETS that may have affected investors' assessment of the financial materiality of a company's emissions.

To overcome these issues, future studies should attempt to achieve a greater sample size of firm-reported greenhouse gas emissions and confirm the accuracy of this data. Future studies should also seek to include more regulatory events in any event study and should analyze the financial materiality for longer periods of time before and after the regulatory event to account for any potential anticipatory or lagging effects of the regulation. Finally, future studies should introduce additional data points into the regression analysis to better explain the relationship between carbon emissions and stock valuations. For example, some research has shown that different industries carry different levels of financial materiality of their greenhouse gas emissions. Performing an event study by industry may provide a greater level of detail into the relationship between carbon emissions and stock valuations. Additionally, any study addressing financial materiality would be significantly enhanced by a survey addressing whether companies or investors believe emissions are financially material and explain the reasons behind that materiality assumption. This may provide critical insight into why investors believe emissions to be financially material rather than simply tracing a correlation between emissions and financial materiality.

CONCLUSION

This study has demonstrated a potential timeline of the financial materiality of greenhouse gas emissions in public companies in relation to specific policy events. Results demonstrate that greenhouse gas emissions become financially material only immediately preceding and immediately following the release of official emission allocations by the governing body. Further research is needed to confirm this relationship. Upon confirmation of this relationship, however, investors and public companies would both benefit by making decisions based on this relationship. Companies that can more effectively predict the implementation of climate policies, and therefore the future market reaction to the implementation of those policies as they relate to the financial materiality of greenhouse gas emissions, can make more effective decisions regarding efforts to reduce greenhouse gas emissions that maximize shareholder value. Investors that are capable of predicting the implementation of climate policies may also make more effective investment decisions by incorporating greenhouse gas emissions as a material risk factor at the appropriate time. Keeping the welfare of capital markets in mind, governments should incorporate the potential effects climate policy may have on public companies and their investors when creating future policies. Climate policy regulating the greenhouse gas emissions of public companies is likely to become more common in the coming years. Therefore, I call on all companies, investors, governments, and other stakeholders to continue to study the effects of climate policy on public companies and incorporate findings into all decision-making processes.

REFERENCES

Bolton, P., & Kacperczyk, M. T. (2020). Do Investors Care About Carbon Risk? *NBER Working Paper No. w26968*.

Brouwers, R., Schoubben, F., Van Hulle, C., & Van Uytbergen, S. (2016). The initial impact of EU ETS verification events on stock prices. *Energy Policy*, 138-149.

Chava, S. (2011). Environmental Externalities and Cost of Capital.

Cohen, M., Fenn, S., & Konar, S. (1997). Environmental and Financial Performance: Are They Related?

da Silva, P. P., Moreno, B., & Figueiredo, N. (2016). Firm-specific impacts of CO2 prices on the stock market value of the Spanish power industry. *Energy Policy*.

Firoz, M. (2019). How does capital market respond to Certified Emission Reductions (CERs) announcements in India: An event study methodology. *Managerial Finance*.

Fisher-Vanden, K., & Thorburn, K. S. (n.d.). Voluntary corporate environmental initiatives and shareholder wealth. *Journal of Environmental Economics and Management*, 430-445.

Fourier, J. (1824). Remarques générales sur les températures du globe terrestre et des espaces planétaires. *Annales de Chimie et de Physique*, 136-167.

Freiberg, D., Park, D., Serafeim, G., & Zochowski, T. R. (2020). Corporate Environmental Impact: Measurement, Data and Information Working Paper 20-098. Harvard Business School.

Griffin, D. P. (2017). *CDP Carbon Majors Report.* Carbon Disclosure Project (CDP).

Griffin, P. A., Lont, D. H., & Sun, E. Y. (2017). The Relevance to Investors of Greenhouse Gas Emission Disclosures. *Contemp Account Res*, 1265-1297.

In, S., Park, K., & Monk, A. (2019). Is 'Being Green' Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns. *Stanford Global Project Center Working Paper*.

Masson-Delmotte, V., Zhai, P., Pörtner, H., Roberts, D., Skea, J., Shukla, P., . . . (eds.). (n.d.). *IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts.*

Matsumura, E., Prakash, R., & Vera-Munoz, S. (2014). Firm-Value Effects of Carbon Emissions and Carbon Disclosure. *The Accounting Review*, 695-724.

Mo, J., Zhu, L., & Fan, Y. (2012). The impact of the EU ETS on the corporate value of European electricity corporations. *Energy*, 3-11.

Monasterolo, I., & de Angelis, L. (2020). Blind to carbon risk? An analysis of stock market reaction to the Paris Agreement. *Ecological Economics*.

Pigou, A. (1932). *The Economics of Welfare* (4th ed. ed.). London: Macmillan and Co.

Pouillet, C. S. (1838). *Mémoire su la chaleur solaire, sur les pouvoirs rayonnants et absorbants de l'air atmosphérique, et sur les températures de l'espace.* Comptes Rendus de l'Académie des Sciences 7.

Rhodes, E., Axsen, J., & Jaccard, M. (2017). Exploring Citizen Support for Different Types of Climate Policy. *Ecological Economics*, 56-69.

Rösler, P., & Ryszka, K. (2020, October 29). *Carbon emissions and stock prices in Europe – an investor's perspective*. Retrieved March 16, 2021

Setzer, J., & Byrnes, R. (2020). *Global trends in climate change litigation: 2020 snapshot.* London: Grantham Research Institute on Climate Change and th eEnvironment and the Centre for Climate Change Economics and Policy.

South Korea Office for Government Policy Coordination. (2016). *Policy and Information*. Retrieved March 18, 2021

The World Bank. (2020, November 1). *Carbon Pricing Dashboard*. Retrieved March 19, 2021

Tsiakas, I., & Oestreich, A. M. (2015). Carbon Emissions and Stock Returns: Evidence from the EU Emissions Trading Scheme. *Journal of Banking & Finance*, 294-308.

Tyndall, J. (1860). Note on the transmission of radiant heat through gaseous bodies. *Royal Institution of Great Britain*, (pp. 37-39). London.

United Nations Climate Framework Convention on Climate Change. (2021). *The Paris Agreement*. Retrieved March 20, 2021

United States Environmental Protection Agency. (2021, April 2). *Laws & Regulations*. Retrieved April 4, 2021

Veld-Merkoulova, Y., & Viteva, S. (2016). Does CO2 Emissions Performance Matter for Stock Prices? In Y. Veld-Merkoulova, & S. Viteva, *Carbon finance: How carbon and stock markets are affected by energy prices and emissions regulations* (pp. 79-128). Springer International Publishing.

Williams III, R. C. (2016, June). Environmental Taxation. National Buruea of Economic Research.

APPENDIX

Regression Summary Output For Each Time Period:

1/1/2010 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.070942271
R Square	0.005032806
Adjusted R Square	-0.002229728
Standard Error	2.039366837
Observations	139

ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.882124159	2.882124159	0.692982042	0.406600707
Residual	137	569.7853422	4.159017096		
Total	138	572.6674663			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.460543111	0.185800985	7.860793138	1.01128E-12	1.093134443	1.827951779	1.093134443	1.827951779
Emission Intensity	-0.043654062	0.05244012	-0.832455429	0.406600707	-0.147350792	0.060042667	-0.147350792	0.060042667

1/12/2010 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.068352016
R Square	0.004671998
Adjusted R Square	-0.002540524
Standard Error	2.149886275
Observations	140

ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.993963441	2.993963441	0.647762077	0.422298379
Residual	138	637.8375173	4.622010995		
Total	139	640.8314808			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.504720506	0.195147999	7.710663279	2.23555E-12	1.118853678	1.890587335	1.118853678	1.890587335
Emission Intensity	-0.044484521	0.055271489	-0.804836677	0.422298379	-0.153773032	0.064803989	-0.153773032	0.064803989

1/13/2010 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.065069443
R Square	0.004234032
Adjusted R Square	-0.002981663
Standard Error	2.143894117
Observations	140

ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.697010613	2.697010613	0.586780929	0.444974887
Residual	138	634.286914	4.596281985		
Total	139	636.9839246			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.496279785	0.194604083	7.688840672	2.51914E-12	1.111488443	1.881071126	1.111488443	1.881071126
Emission Intensity	-0.042220853	0.055117436	-0.766016272	0.444974887	-0.151204755	0.066763049	-0.151204755	0.066763049

1/14/2010 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.064598739
R Square	0.004172997
Adjusted R Square	-0.003043141
Standard Error	2.187674428
Observations	140

ANOVA

	df	SS	MS	F	Significance F
Regression	1	2.767633915	2.767633915	0.578286779	0.448281953
Residual	138	660.4568774	4.785919401		
Total	139	663.2245113			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.512073638	0.198578079	7.614504315	3.78028E-12	1.119424499	1.904722776	1.119424499	1.904722776
Emission Intensity	-0.042770074	0.056242985	-0.760451694	0.448281953	-0.153979528	0.068439381	-0.153979528	0.068439381

1/1/2011 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.012911702
R Square	0.000166712
Adjusted R Square	-0.005784677
Standard Error	1.134832454
Observations	170

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.036075482	0.036075482	0.028012292	0.867281219
Residual	168	216.3579093	1.287844698		
Total	169	216.3939848			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.211783361	0.093755363	12.92494981	5.66938E-27	1.026692912	1.39687381	1.026692912	1.39687381
Emission Intensity	-0.004463751	0.026670163	-0.167368732	0.867281219	-0.057115593	0.04818809	-0.057115593	0.04818809

1/1/2012 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.035263034
R Square	0.001243482
Adjusted R Square	-0.001272278
Standard Error	1.135900323
Observations	399

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.637750298	0.637750298	0.494276797	0.482437766
Residual	397	512.2370093	1.290269545		
Total	398	512.8747596			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.108543941	0.060833257	18.2226631	2.35783E-54	0.988948348	1.228139534	0.988948348	1.228139534
Emission Intensity	-0.021815587	0.031030002	-0.703048218	0.482437766	-0.08281925	0.039188075	-0.08281925	0.039188075

5/11/2012 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.000623188							
R Square	3.88364E-07							
Adjusted R Square	-0.002563713							
Standard Error	1.803836754							
Observations	392							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.000492831	0.000492831	0.000151462	0.990186984			
Residual	390	1268.992544	3.253827035					
Total	391	1268.993037						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.16445971	0.097250668	11.97379657	2.37239E-28	0.973258544	1.355660876	0.973258544	1.355660876
Emission Intensity	-0.000533337	0.043336069	-0.012306989	0.990186984	-0.08573488	0.084668207	-0.08573488	0.084668207

5/14/2012 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.002493603							
R Square	6.21806E-06							
Adjusted R Square	-0.002531837							
Standard Error	1.737638263							
Observations	396							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.007397285	0.007397285	0.00244993	0.960548498			
Residual	394	1189.638373	3.019386734					
Total	395	1189.645771						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.147182318	0.093176578	12.31191723	1.07236E-29	0.963996867	1.330367769	0.963996867	1.330367769
Emission Intensity	-0.002065445	0.041728895	-0.049496764	0.960548498	-0.084104586	0.079973695	-0.084104586	0.079973695

5/15/2012 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.002927858							
R Square	8.57235E-06							
Adjusted R Square	-0.002529477							
Standard Error	1.711730897							
Observations	396							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.009896258	0.009896258	0.003377536	0.953685235			
Residual	394	1154.42893	2.930022665					
Total	395	1154.438826						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.134545016	0.091787359	12.36058018	6.93512E-30	0.954090773	1.314999258	0.954090773	1.314999258
Emission Intensity	-0.002388983	0.041106737	-0.058116575	0.953685235	-0.083204958	0.078426993	-0.083204958	0.078426993

1/1/2013 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.031597809
R Square	0.000998422
Adjusted R Square	-0.001511633
Standard Error	0.98348973
Observations	400

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.38474279	0.38474279	0.397768906	0.528605719
Residual	398	384.9663159	0.96725205		
Total	399	385.3510586			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.059583139	0.052617829	20.13734034	1.07736E-62	0.956139521	1.163026756	0.956139521	1.163026756
Emission Intensity	-0.015714366	0.024916179	-0.630689231	0.528605719	-0.064698137	0.033269405	-0.064698137	0.033269405

1/1/2014 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.016053208
R Square	0.000257705
Adjusted R Square	-0.000507794
Standard Error	1.409820588
Observations	1308

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.669123774	0.669123774	0.336650113	0.561869341
Residual	1306	2595.797881	1.987594089		
Total	1307	2596.467005			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.187637234	0.040819137	29.09510866	6.9454E-144	1.107558982	1.267715486	1.107558982	1.267715486
Emission Intensity	0.00676716	0.011663182	0.580215574	0.561869341	-0.016113461	0.02964778	-0.016113461	0.02964778

1/27/2014 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.017909743
R Square	0.000320759
Adjusted R Square	-0.000437148
Standard Error	1.515960397
Observations	1321

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.972609623	0.972609623	0.423216753	0.515449595
Residual	1319	3031.241286	2.298135926		
Total	1320	3032.213896			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.243183632	0.043930992	28.29855616	4.5859E-138	1.157001388	1.329365876	1.157001388	1.329365876
Emission Intensity	0.008728345	0.013416848	0.650551114	0.515449595	-0.017592346	0.035049036	-0.017592346	0.035049036

1/28/2014 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.015044817							
R Square	0.000226347							
Adjusted R Square	-0.000531632							
Standard Error	1.509044468							
Observations	1321							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.68001893	0.68001893	0.298618649	0.584842125			
Residual	1319	3003.646858	2.277215207					
Total	1320	3004.326877						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.246093624	0.043712982	28.50626015	1.1741E-139	1.160339064	1.331848184	1.160339064	1.331848184
Emission Intensity	0.00732717	0.013408426	0.546460108	0.584842125	-0.018977	0.03363134	-0.018977	0.03363134

1/29/2014 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.013065554							
R Square	0.000170709							
Adjusted R Square	-0.000587312							
Standard Error	1.523953749							
Observations	1321							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.52301983	0.52301983	0.225203213	0.635182169			
Residual	1319	3063.291803	2.322435029					
Total	1320	3063.814823						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.263171379	0.044145309	28.61394345	1.7516E-140	1.176568694	1.349774063	1.176568694	1.349774063
Emission Intensity	0.006415219	0.013518366	0.474555806	0.635182169	-0.020104627	0.032935065	-0.020104627	0.032935065

3/17/2014 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.018405411							
R Square	0.000338759							
Adjusted R Square	-0.000419134							
Standard Error	1.476019753							
Observations	1321							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.973794462	0.973794462	0.44697472	0.503892105			
Residual	1319	2873.618658	2.178634312					
Total	1320	2874.592452						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.312994353	0.042745277	30.71671189	9.5366E-157	1.229138202	1.396850505	1.229138202	1.396850505
Emission Intensity	0.008757778	0.013099432	0.66856168	0.503892105	-0.016940217	0.034455773	-0.016940217	0.034455773

3/18/2014 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.017615013							
R Square	0.000310289							
Adjusted R Square	-0.000447626							
Standard Error	1.483397565							
Observations	1321							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.900866871	0.900866871	0.409397789	0.52238644			
Residual	1319	2902.417736	2.200468336					
Total	1320	2903.318603						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.322803291	0.042958937	30.79227243	2.4605E-157	1.238527989	1.407078594	1.238527989	1.407078594
Emission Intensity	0.008423461	0.013164909	0.639842003	0.52238644	-0.017402984	0.034249907	-0.017402984	0.034249907

3/19/2014 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.016688066							
R Square	0.000278492							
Adjusted R Square	-0.000479447							
Standard Error	1.497376509							
Observations	1321							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.823834231	0.823834231	0.367432698	0.544511304			
Residual	1319	2957.377926	2.242136411					
Total	1320	2958.20176						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.327479349	0.043363765	30.61264064	6.1572E-156	1.24240987	1.412548827	1.24240987	1.412548827
Emission Intensity	0.008055272	0.013288969	0.606162271	0.544511304	-0.018014552	0.034125095	-0.018014552	0.034125095

12/2/2014 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.054180632							
R Square	0.002935541							
Adjusted R Square	0.002221823							
Standard Error	1.655996678							
Observations	1399							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	11.27925006	11.27925006	4.113024558	0.042743638			
Residual	1397	3831.028021	2.742324997					
Total	1398	3842.307272						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.373172702	0.046650535	29.43530463	1.4165E-148	1.281660048	1.464685355	1.281660048	1.464685355
Emission Intensity	0.028286661	0.01394765	2.028059308	0.042743638	0.000926065	0.055647257	0.000926065	0.055647257

12/3/2014 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.052962544
R Square	0.002805031
Adjusted R Square	0.002090708
Standard Error	1.671343464
Observations	1398

ANOVA

	df	SS	MS	F	Significance F
Regression	1	10.96918665	10.96918665	3.92683824	0.047717102
Residual	1396	3899.57101	2.793388975		
Total	1397	3910.540196			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.386465246	0.047100909	29.43606107	1.4688E-148	1.294069052	1.478861441	1.294069052	1.478861441
Emission Intensity	0.027895902	0.014077285	1.981625151	0.047717102	0.000280988	0.055510816	0.000280988	0.055510816

12/4/2014 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.052701739
R Square	0.002777473
Adjusted R Square	0.002061592
Standard Error	1.694606191
Observations	1395

ANOVA

	df	SS	MS	F	Significance F
Regression	1	11.14157283	11.14157283	3.879796313	0.049068353
Residual	1393	4000.264369	2.871690143		
Total	1394	4011.405942			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.395734153	0.047812066	29.19209065	1.4306E-146	1.301942733	1.489525572	1.301942733	1.489525572
Emission Intensity	0.028116814	0.014274525	1.969719856	0.049068353	0.00011493	0.056118699	0.00011493	0.056118699

12/31/2014 SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.058773369
R Square	0.003454309
Adjusted R Square	0.002739427
Standard Error	1.700887268
Observations	1396

ANOVA

	df	SS	MS	F	Significance F
Regression	1	13.97905422	13.97905422	4.831997809	0.028100138
Residual	1394	4032.866395	2.8930175		
Total	1395	4046.845449			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.395733498	0.047975124	29.09285851	8.2335E-146	1.30162227	1.489844725	1.30162227	1.489844725
Emission Intensity	0.031228651	0.014206591	2.198180568	0.028100138	0.003360048	0.059097254	0.003360048	0.059097254

1/2/2015 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.017186618							
R Square	0.00029538							
Adjusted R Square	-0.00037873							
Standard Error	2.062766655							
Observations	1485							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	1.864448976	1.864448976	0.438177727	0.508106146			
Residual	1483	6310.174302	4.255006272					
Total	1484	6312.038751						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.476235352	0.056113698	26.30793188	1.6733E-125	1.366164691	1.586306014	1.366164691	1.586306014
Emission Intensity	0.009883942	0.014931555	0.661949943	0.508106146	-0.019405273	0.039173157	-0.019405273	0.039173157

1/1/2016 SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.025376705							
R Square	0.000643977							
Adjusted R Square	5.99E-05							
Standard Error	3.265578284							
Observations	1713							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	11.7576472	11.7576472	1.102554905	0.293854377			
Residual	1711	18246.10662	10.66400153					
Total	1712	18257.86427						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.020406014	0.083046249	24.32868463	1.5887E-112	1.857523133	2.183288894	1.857523133	2.183288894
Emission Intensity	0.02429172	0.023134395	1.050026145	0.293854377	-0.021082959	0.069666399	-0.021082959	0.069666399

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