What the capital markets tell us about danger in sustainability: how global sea-level affects stock performances (PD ratio and returns)

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Abstract

This paper uses global average sea-level obtained from the United States Environmental Protection Agency (EPA) as a proxy on how the change in environmental sustainability affects a company's stock performance. Numerous financial literature has explored the relationship between environmental variables – temperature, greenhouse gas emission, environmental regulation, etc. – on company's capital budgeting decision, stock performance, and real estate valuation. This paper contributes to the rising interest in Environmental, Social and Corporate Governance (ESG). Using annual company stock data from Centre of Research in Security Prices (CRSP) and annual company characteristics data from COMPUSTAT, this paper attempts to answer the following questions: Are some industry's price-to-dividend ratio and stock returns susceptible to change in global sea-level? Can global sea-level predict price-to-dividend ratio and stock returns at the industry-level over time?.

Contents

List of Tables

List of Figures

1 Introduction

The world has experienced record-breaking incurred economic costs resulting from natural hazard. For example, the United States has encountered the most amount of natural hazards causing an estimated cost of at least one billion US dollars in 2017. These are all results from rising temperature, sea-level, and greenhouse gas emission, etc.

With media increasingly broadcasting concerns on climate change, nuclear energy, and sustainability, environmental variables are slowly gaining attraction in finance and economics. Many have concluded that environmental issue is highly associated with economic risks, which in turn will affect firms and households negatively. Such implication ultimately affects a firm's valuation.

Naturally, concern in environmental sustainability is explored more so than ever. With the constant rise in environmental issues, there is rising pressure on corporate regulations and environmental performances. There are numerous organizations that disclose a company's environmental performances. In addition, there are new financial products and economic policies, such as Green Bonds and carbon tax, encouraging companies for a environmental friendly business model. Therefore, studies have looked into how capital markets and managers respond to companies' sustainability scores and environmental policies. However, less is examined on how physical environmental changes impact financial indicators exogenously.

This paper will use global sea-level as a proxy for the world's environmental risk. This metric will be used to see the effect on price-to-dividend (PD) ratio and stock returns of firms that are believed to have significant impact from changes in environmental factor - energy, materials, insurance, and real estate firms. The two key questions this paper will attempt to answer are: Are some industry's PD ratio and stock returns susceptible to change in global sea-level? Can global sea-level predict the industry's PD ratio and stock returns over time?

Through panel data regression, we find that real estate firms have economically significant fall in PD ratio from an increase in global sea-level while energy, materials and insurance firms do not. Additionally, the effect of change in global sea-level on each industry's stock return is insignificant. From cross-validation, the result suggests that annual PD ratio can be predicted from the change in global sea-level at the industry level.

The remaining sections of the paper is constructed as follows: literature review, data, empirical methods, results, and conclusion.

2 Literature Review

Corporations have shown significant responsive behaviors towards natural disaster events. Prior researches have shown that people use heuristics for forecasting (Tversky and Kahneman 1973). Because of this, managers overreact to hurricane events when their firms are located in the neighborhood of the disaster; increase in salience of an event could lead to bias, and thus overestimation of risky events. Ultimately, managers may choose a capital budgeting strategy that is sub-optimal (Dessaint and Matray 2017).

There is also economically significant relationship between the capital market and long-term temperature change. Global warming decreases present value of asset valuation (Bensal, Kiku, and Ochoa 2016), and is associated with increase in economic risk, such as increase in probability of natural hazards (Nordhaus 2007). Therefore, using forward equity valuation where future economic risks are discounted in present value, asset valuation will decline as long-run temperature increases. On the other hand, there is also significant psychological impact from temperature change. In general, there is negative correlation between temperature and stock market returns, as previous psychological literature show that lower temperature leads to aggression; therefore, investors will be less risk-averse (Cao and Wei 2005).

Environmental policy also affects asset valuation, for example commodity prices. Greater environmental uncertainty can lead to fall in oil prices, since oil producers would be less inclined to have oil reserves in sub-optimal environmental conditions. Therefore, supply of oil will increase, leading to cheaper oil (Barnett 2018). This also implies increasing stock prices from cheaper factor of production.

Now with information on companies' green house gas emission available, investors can estimate a company's emission volume. This implies that companies, regardless of disclosing their green house gas emission data, could have their stock performances reflected by appropriate factors from firm's balance sheet identifying emission volume (Griffin, Lont, and Sun 2012), (Matsumura, Prakash, and Vera-Muñoz 2011). Generally speaking, financial and tech firms are least exposed to carbon risks, whereas material and energy firms have the highest carbon risks by nature of the industries' business models (Görgen et al. 2019). With increasing attention towards environmental sustainability, investors are also looking into environmental scores for firms. It turns out firms with carbon disclosure imply that "market is likely to respond negatively" (Lee, Park, and Klassen 2015). However, other literature argue that carbon disclosure is a sign of "risk reduction, a good reputation, and customer loyalty" that could potentially benefit the firm in the capital market (Jacobs, Singhal, and Subramanian 2010). Firms with higher environmental scores from Climate Counts also have lower volatility in aggregate returns (Beautty and Shimshack 2010).

Research has also shown that coastal cities have significant dollar-amount loss in real estate value from rising sea-level. From predicting future tidal catastrophic events, there is significant incurred loss on real estate dollar amount in coastal cities like Miami (McAlpine and Porter 2018). In general, an increase in global sea-level increases welfare cost. However, this is only for selected sectors and not all: economies that rely on agriculture are hit hardest and energy consumption decreases (Bosello, Roson, and Tol 2007).

Lastly, rising catastrophic events can lead to changing dynamics in the insurance market. With increasing losses from natural hazards, households and corporations could increase their insurance participation rate, potentially benefitting insurance companies (Smith and Matthews 2015).

Therefore, researches have shown how environmental risks have significant impact on capital markets and several industries - namely energy, materials, insurance and real estate. This paper will attempt to uncover whether sea-level change is a significant proxy for economic risk that could affect these industries' stock performances.

3 Data

In order to uncover how global sea-level affects stock performances, three main data sets will be used. Firm-level data on security and financial statement will be extracted from Centre of Research in Security Prices (CRSP) and COMPUSTAT respectively; both are panel data sets that will be obtained from Wharton Research Data Services (WRDS). CRSP will provide each firm's monthly historical security mean bid-ask prices and COMPUSTAT will provide each firm's annual financial characteristics - such as total assets, long term debt, dividends-per-share, firm's industry group, etc. CRSP data will be compressed from monthly values to annual averages. COMPUSTAT has Global Industry Classification Standard (GICS) from S&P Global, which indicates the industry group a firm belongs to. For the purpose of this paper, we are interested in energy (1010), materials (1510), insurance (4030) and real estate (4040 and 6010) firms. Because real estate has two GICS identifier, the paper will convert firm's GICS identifier to 6010 if its GICS identifier is 4040.

When using the cross-validation test, the paper will use the entire data set. Since the media & entertainment industry group has two GICS identifier (2530 and 5020), firms with GICS identifier of 2530 will be converted to 5020.

A time series data on global average sea-level (in inches) will be extracted from the United States Environmental Protection Agency (EPA), which provides the annual average difference in sea-level from 1880 as a baseline. The World Bank Open Data Base provides time series data on annual macroeconomic variables, which will be used as control variables. The combined data sets will include 6082 company's (and 24 industry group's) financial statement and security prices, including 215 energy firms, 220 materials firms, 128 insurance firms, and 208 real estate firms from 2004 to 2013. On top of that, we have the global average sea-level in inches and U.S. macroeconomic variables from 2004 to 2013.

4 Empirical Methods

This section will discuss the regression framework and methodologies used to uncover the initial question of the paper - are PD ratio and stock returns for energy, materials, insurance and real estate firms affected by the change in global sea-level; is global sea-level a significant predictor for PD ratio and stock returns at the industry level.

This paper will use a panel data regression to uncover whether energy, materials, insurance and real estate firms' PD ratios and stock returns are affected by the change in global sea-level. Then, to verify that change in global sea-level can predict PD ratios and stock returns at the industry level, the paper will leverage cross-validation testing.

First let us define a couple of parameters. ΔSL_y is the change in global sea-level at a given year y where

$$\Delta SL_y = SL_y - SL_{y-1} \tag{1}$$

SL_y is global sea-level at year y and SL_{y-1} is the global sea-level of the previous year, all in inches. Figure 1 is a graph showing the annual change in sea-level from 2004 to 2013.

The PD ratio of firm i at year y is defined as

$$PD_{i,y} = \frac{Price_{i,y}}{DPS_{i,y}} \tag{2}$$

Where $Price_{i,y}$ is the average annual mean of bid-ask stock price and $DPS_{i,y}$ is the dividends per share at pay date.

Lastly, the return of the stock of firm i at year y is defined as

$$Return_{i,y} = \frac{Price_{i,y} - Price_{i,y-1}}{Price_{i,y}} \tag{3}$$

4.1 OLS

The panel data regressions that will uncover the relationship between industry average's PD ratio and stock returns versus change in sea-level are

$$lnPD_{i,y} = \Sigma_{j=1}^{k} \beta_j Industry_{i,j} \times \Delta SL_y + \epsilon_{i,y} \tag{4}$$

$$Return_{i,y} = \Sigma_{j=1}^{k} \delta_j Industry_{i,j} \times \Delta SL_y + \epsilon_{i,y} \tag{5}$$

For firm i at year y, $lnPD_{i,y}$ is the firm's log equivalent PD ratio. $Industry_{i,j}$, where j indexes the industry groups listed on COMPUSTAT is a dummy variable where,

$$Industry_{i,j} = \begin{cases} 0 \text{ if i} \notin j \\ 1 \text{ if i} \in j \end{cases}$$

We are interested in the β_j and δ_j coefficients for energy, materials, insurance and real estate firms. Energy and materials are considered the biggest contributor to carbon emission. On top of that, agriculture businesses experience welfare loss and demand for energy decreases from increase in sea-level (Bosello, Roson, and Tol 2007). Therefore, the hypothesis is that β_j and δ_j coefficients for these two industries are negative. Insurance firms may gain from increasing probability in catastrophic events, as more risk averse managers would want to hedge their assets. However, increasing probability in catastrophic events could imply potential losses for insurance firms. A primary example of this is when American Insurance Group (AIG) which had \$ 1 trillion worth of asset went bankrupt because of the Great Financial Crisis that occurred in 2008. Therefore, β_j and δ_j coefficient for insurance firms is ambiguous at this point. Lastly, β_j and δ_j coefficient for real estate industries should be negative, as catastrophic events could lead to significant losses in real estate values. $\epsilon_{i,y}$ is the error term for firm i at year y.

The paper will include firm characteristics variables and macro-economic variables as controls to resolve for omitted variable bias.

$$lnPD_{i,y} = \Sigma_{j=1}^{k} \beta_j Industry_{i,j} \times \Delta SL_y + \Sigma X_{i,y} + \Sigma Macro_y + \epsilon_{i,y} \tag{6}$$

$$Return_{i,y} = \Sigma_{j=1}^{k} \delta_j Industry_{i,j} \times \Delta SL_y + \Sigma X_{i,y} + \Sigma Macro_y + \epsilon_{i,y} \tag{7}$$

For firm i, $X_{i,y}$ denotes depreciation and amortization, intangible assets, revenue, cost of goods sold and capital expenditure, all denominated by the firm's respective total assets at year y.

$Macro_y$ includes log equivalent GDP, real interest rate and inflation rate, all indexed at year y for the United States. These controls were selected based off of control variables related literature have included in their empirical models.

4.2 Cross-Validation

For the cross-validation test, we consider the following dummy variable

$$Firstsample_y = \begin{cases} 0 \text{ if y} > 2008 \\ 1 \text{ if y} \leq 2008 \end{cases}$$

$Firstsample_y$ is a year dummy variable that equals 1 if the observation is from 2004 to 2008. For observations after 2008, $Firstsample_y$ equals 0.

The paper will regress β_j and δ_j's from 2009 to 2013 ($Firstsample = 0$) on β_j and δ_j's from years 2004 to 2008 ($Firstsample = 1$) respectively to determine whether effect of global sea-level on PD ratio and stock returns could be predicted over time.

$$\beta_{j,Firstsample=0} = \alpha + \phi\beta_{j,Firstsample=1} \tag{8}$$

$$\delta_{j,Firstsample=0} = \alpha + \gamma\delta_{j,Firstsample=1} \tag{9}$$

$\beta_{j,Firstsample=1}$ is the β coefficient for industry group j from 2004 to 2008 and $\beta_{j,Firstsample=0}$ is the β coefficient for industry group j from 2009 to 2013. Similarly, $\delta_{j,Firstmple=1}$ is the δ coefficient for industry group j from 2004 to 2008 and $\delta_{j,Firstmple=0}$ is the δ coefficient for industry group j from 2009 to 2013. In this cross validation strategy, the paper is interested in whether ϕ and δ are significantly different from 0.

5 Results

This section will discuss the results obtained from Section 4.

5.1 OLS

We will first examine the OLS panel data regression that will uncover each industry's exposure towards change in sea-level on PD ratio and stock returns. Again, for the purpose of this paper, we are only concerned with β_j and δ_j coefficients for energy, materials, insurance and real estate industry groups.

From Table 1 column (1), a 1% increase in global sea-level decreases the PD ratio by 0.914 percentage point at a 0.1% significance level for real estate firms. This result supports previous literature arguing real estate dollar valuation incurs substantial losses due to sea-level rise, mainly from rising probability in catastrophic events that could decrease real estate value.

However, energy, material and insurance firms have statistically insignificant changes in PD ratio from the change in global sea-level. For energy and material industries, we can assert that although these firms are primary contributors to greenhouse gas emission, capital markets do not necessarily penalize these firms when environmental sustainability is worsening. As stated in the introduction and literature review, past related literature presents the significance of insurance companies in catastrophic events. However, as hypothesized in Section 4, insurance companies can either have potential benefits or potential losses from the change in environmental sustainability. The regression shows the effect of global sea-level change is statistically insignificant on change in PD ratio for insurance companies, and this may be because of the ambiguous potential gains or losses that insurance companies obtain from the change in economic uncertainty.

On the other hand, from Table 1 column (2), there is no significant causality from the change in sea-level on a company's stock return for the four industry groups the paper is interested in. Although energy and real estate firms do have negative stock returns from an increase in global sea-level, the empirical model suggests that such a relationship is insignificant.

5.2 Cross-Validation

Finally, the relation between every industry's β_j and δ_j from observations in 2004 to 2008 versus 2009 to 2013 will be examined to determine whether investors can predict PD ratio and stock returns from change in sea-level.

In Figure 2, the graph shows an upward slope of 0.277 that is significant at at 0.1% significance level. This result suggests that annual PD ratio can be predicted from change in sea-level at the industry level.

The predictability of returns using change in sea-level on the other hand can be interpreted in two cases. If we include all industry groups in the cross-validation, we have $\gamma = 0.306$ that is significant at the 5% significance level. This suggests that change in global sea-level can predict the stock return of a company for a given industry.

However, we note in Table 4 and Figure 3, banks (GICS = 4010) have significantly low δ_j compared to other industry groups. Thus, if we exclude banks from the cross-validation test, γ becomes insignificant. This suggests that stock returns cannot be predicted from change in global sea-level.

6 Conclusion

It is well established that a rise in sea-level is a strong indicator for rising economic risk and environmental uncertainty, namely an increase in the probability of economic loss from catastrophic events. Such catastrophic events, like hurricane, floods, and earthquakes, can incur significant losses to firms that have physical assets located in the affected area.

Using panel data regression, the paper uncovered that real estate firms' PD ratio fall by 0.938 percentage points from 1% increase in global sea-level on average. However, previous literature suggesting that energy and materials industries exposed to change in sea-level cannot be strongly supported from this paper's results. On the other hand, the effect of changing global sea-level is insignificant on industry-level stock returns for the four industries.

Next, using cross-validation strategy, the paper showed that, investors can predict PD ratio at the industry group level from global sea-level. However, making a strong argument for the predictability of stock returns from global sea-level is ambiguous as the γ is significant at the 5% significance level but insignificant without the outlier.

One could argue that the significant result derived for real estate in Table 1 could be by chance, as energy, materials and insurance industries showed insignificant results. On the other hand, one could argue that energy, materials and insurance firms have insignificant results because global sea-level itself is not a precise estimate for forecasting catastrophic events. There are other geographical variables, such as wind speed and temperature, that can affect the probability of catastrophic events. On top of that, not all locations are affected by catastrophic events similarly (Bosello, Roson, and Tol 2007). Thus, scholars could implement more geographical factors to engineer a better predictor for catastrophic events. On top of that, future research could also examine cross-sectional variation not only of industries but also in terms of locations such as states and counties. Furthermore, papers can attempt to leverage an instrument variable to look at how environmental factor affects stock performances through economic losses.

Lastly, some could argue that 24 industry groups is insufficient sample to show whether PD ratio can be predicted from global sea-level. Therefore, further research can perform cross-validation on sub-industries groups.

7 Appendix

Table 1: Effect of Change in Sea-Level on PD ratio and Stock Returns

	(1)	(2)
Industry Group (GICS)	Log Equivalent PD Ratio	Stock Return
Energy (1010)	-0.191	-0.327
	(0.158)	(0.209)
Materials (1510)	0.273	1.309
	(0.146)	(1.736)
Insurance (4030)	0.118	-0.658
	(0.166)	(1.002)
Real Estate (6010)	-0.914***	-0.879
	(0.137)	(0.599)
Macro Controls	Yes	Yes
Firm Controls	Yes	Yes
N	18362	39191
Clusters	3098	6082
R-squared	0.119	0.000438

[1] The unit of observation is firm i at year y. Robust standard errors, adjusted for clustering by firm identified as permno in CRSP and COMPUSTAT. The dependent variable is the log equivalent price-dividend ratio column (1) and stock return for column (2). Macro Controls include United State's log equivalent GDP, inflation rate and real interest rate at year y. Firm Controls include total intangible assets, long term debt, depreciation and amortization, research and development expenditure, and capital expenditure all denominated by total assets at year y for firm i. The samples include all firms cross-listed on CRSP and Compustat from 2004 to 2013. The significance level of the coefficients are denoted as follows: *5% **1% ***0.1%

[2] * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: β coefficients for 2004-2008 and 2009-2013

Industry Group (GICS)	(1) Test-Sample	(2) Out-Sample
Energy (1010)	-0.661	-0.010
Materials (1510)	0.247	0.310
Capital Goods (2010)	0.681	0.018
Commercial & Professional Services (2020)	-0.479	-0.533
Transportation (2030)	0.487	-0.558
Automobiles & Components (2510)	-2.040	-0.685
Consumer Durables & Apparel (2520)	-0.081	-0.115
Hotel (2530)	0.015	-0.324
Retailing (2550)	0.074	-0.420
Food & Staples Retailing (3010)	-0.770	-0.056
Food, Beverage & Tobacco (3020)	-1.436	-0.660
Household & Personal Products (3030)	-0.842	-0.087
Health Care Equipment & Services (3510)	0.975	-0.126
Pharmaceuticals, Biotechnology & Life Sciences (3520)	0.539	-0.400
Banks (4010)	-1.205	-0.352
Diversified Financials (4020)	-0.299	-0.459
Insurance (4030)	1.117	-0.308
Software & Services (4510)	-0.570	-0.615
Technology Hardware & Equipment (4520)	0.223	-0.396
Semiconductors & Semiconductor Equipment (4530)	0.386	-0.220
Telecommunication Services (5010)	-2.704	-1.351
Media & Entertainment (5020)	-2.015	-1.462
Utilities (5510)	-1.661	-0.977
Real Estate (6010)	-1.601	-0.670

Each firm cross-listed on CRSP and COMPUSTAT has a GICS identifier that signals an industry group. The values in column (1) are the β_j coefficients for each industry from 2004 to 2008. The values in column (2) are the β_j coefficients for each industry from 2009 to 2013.

Table 3: δ coefficients for 2004-2008 and 2009-2013

Industry Group (GICS)	(1) Test-Sample	(2) Out-Sample
Energy (1010)	-3.585	-0.413
Materials (1510)	-4.923	2.391
Capital Goods (2010)	-5.204	-0.682
Commercial & Professional Services (2020)	-4.908	-0.724
Transportation (2030)	-4.742	-0.492
Automobiles & Components (2510)	-5.931	-0.571
Consumer Durables & Apparel (2520)	-5.885	-0.307
Hotel (2530)	-4.719	-0.645
Retailing (2550)	-4.721	-0.424
Food & Staples Retailing (3010)	-3.340	-0.418
Food, Beverage & Tobacco (3020)	-4.692	-0.354
Household & Personal Products (3030)	-4.834	-0.262
Health Care Equipment & Services (3510)	-4.455	-0.462
Pharmaceuticals, Biotechnology & Life Sciences (3520)	-6.444	-0.699
Banks (4010)	-10.019	-2.184
Diversified Financials (4020)	-7.248	-3.063
Insurance (4030)	-5.980	0.178
Software & Services (4510)	-4.720	-0.244
Technology Hardware & Equipment (4520)	-5.731	-0.403
Semiconductors & Semiconductor Equipment (4530)	-5.831	-0.370
Telecommunication Services (5010)	-4.569	-0.352
Media & Entertainment (5020)	-4.816	-0.167
Utilities (5510)	-5.808	-0.862
Real Estate (6010)	-7.301	0.221

Each firm cross-listed on CRSP and COMPUSTAT has a GICS identifier that signals an industry group. The values in the column (1) are the δ_j coefficients for each industry from 2004 to 2008. The values in column (2) are the δ_j coefficients for each industry from 2009 to 2013.

Table 4: Cross-Validation Test

	PD	Stock Return	
	(1)	(2)	(3)
	Out-Sample	Out-Sample	Out-Sample Without Outlier
Test-Sample PD	0.277***		
	(0.0635)		
Test-Sample Return		0.306*	0.237
		(0.123)	(0.255)
N	24	24	23
R-squared	0.482	0.210	0.0737

[1] The unit of observation is industry groups, with robust standard errors. For column (1), the dependent variable is β_j for $Firstsample = 0$ and the independent variable is β_j for $Firstsample = 1$. For column (2) and (3), the dependent variable is the δ_j for $Firstsample = 0$ and the independent variable is the δ_j coefficient for $Firstsample = 1$. In column (3), industry group 4010 (Banks) is excluded because its δ_j is an outlier. The significance level of the coefficients are denoted as follows: *5% **1% ***0.1%

[2] * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$;

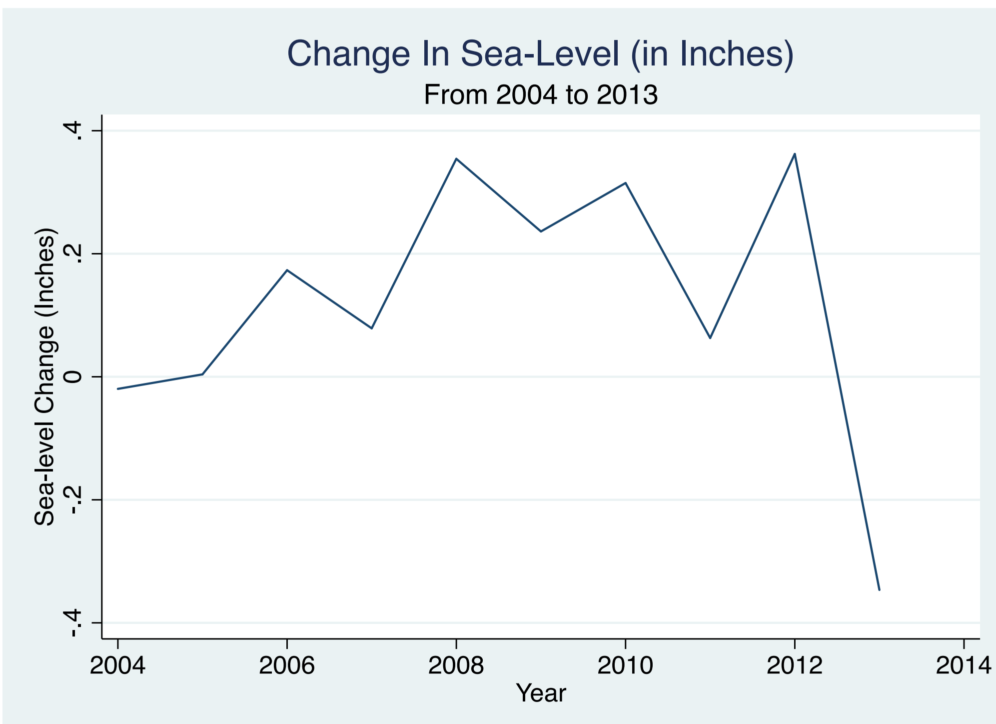

Figure 1: Change in Global Sea-Level

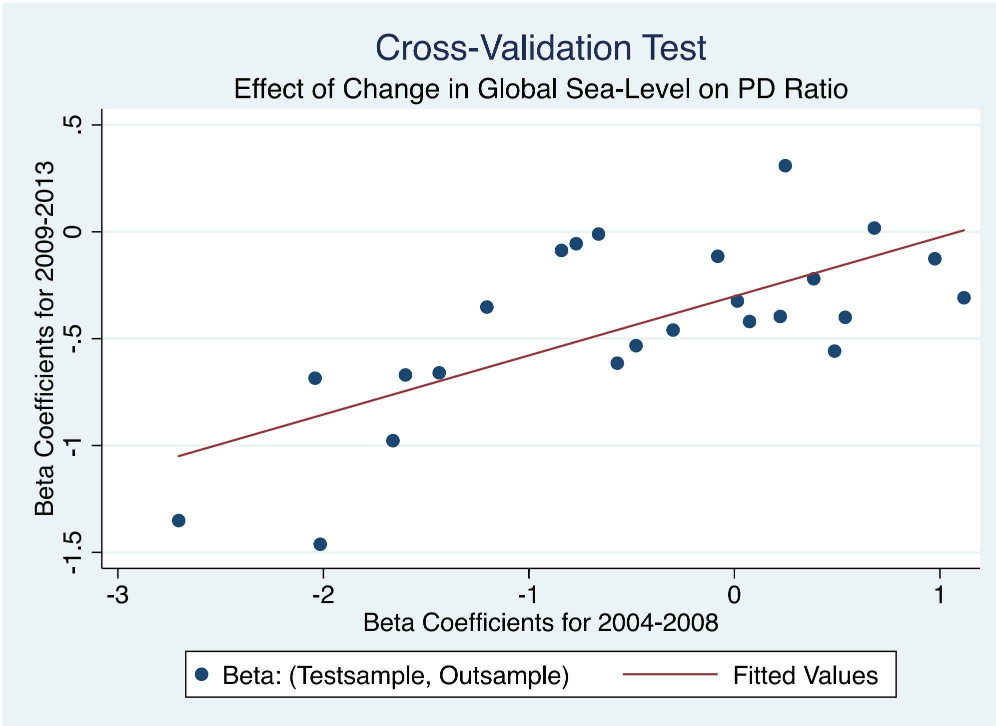

Figure 2: Scatterplot for β_j from Testing-Sample and Out-of-Sample

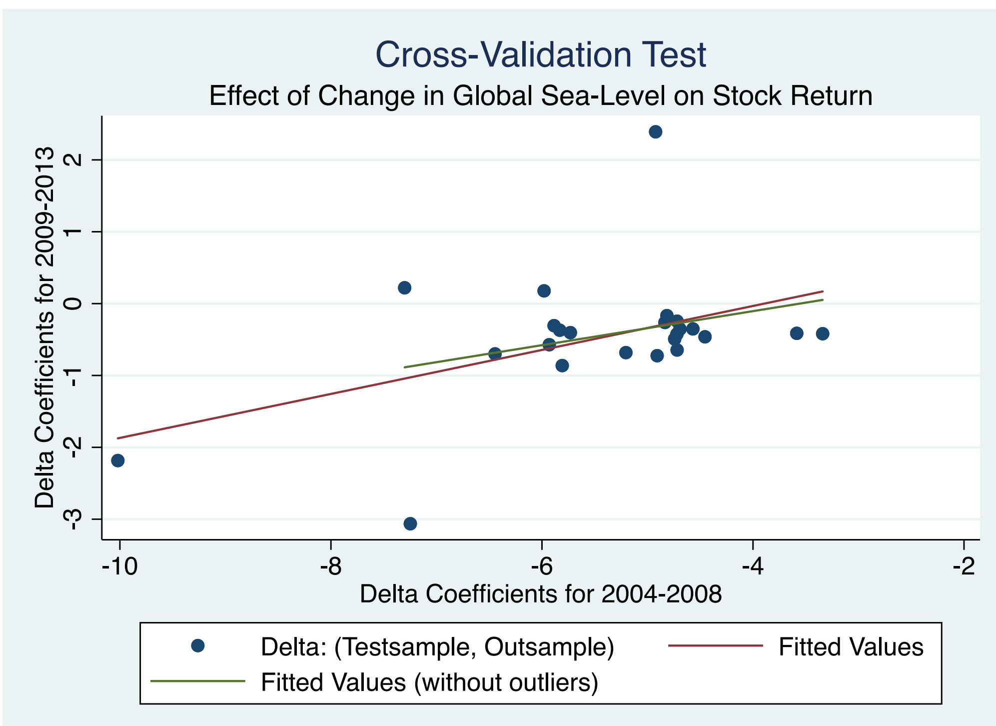

Figure 3: Scatterplot for δ_j from Testing-Sample and Out-of-Sample

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