

Impact of SO₂ Allowance Price on Value of Firms

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Abstract

We did not find any study, besides a few event studies, in the environmental literature that has estimated the effect of the regulatory cost on the financial value of individual firms in the United States. Cost-benefit methodology does not deal with the impact on the stock value of a firm. To fill this gap, time series models are used to establish a functional relationship between stock price and prices of the SO₂ allowance, coal, natural gas and electricity. Stock prices and the SO₂ price are found to be non-stationary. For most of the firms, using the generalized conditional heteroscedasticity model we find that the exogenous variables (natural gas, coal and electricity prices) are largely insignificant in affecting the stock prices of firms. Hence, we dropped these variables from the functional specification for the relationship between the stock price and the SO₂ allowance price. We find that the regulatory cost represented by the SO₂ price is neutral in affecting the stock price of electric generation firms. We speculate or theorize that the public is indirectly paying for the environmental protection cost, otherwise SO₂ price would have dampened the stock prices of firms.

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1 Introduction

Production and consumption externalities effect the environment. Environmental externalities are not generally internalized because the market system does not have built-in mechanism to constrain firm and individual behavior. In theory, cost of monitoring the firm or individual behavior seems to be too high. Society has not evolved strong informal institutions for the protection of environmental media. The cost of creating informal arrangements and their enforcement to constrain behavior with respect to the environment must be high for a society (see North (1981)). Voluntary arrangements are not sufficient to protect the common good. There are free riders who maximize return on their investment without the existence of constraints on their behavior. Market mechanism simply is not efficient to constrain firms' behavior in preventing imposition of significant cost to the environment. Ethics and habits or taboos are not sufficient arrangements to override the concern for profits and cannot be enforced because enforcement and monitoring costs are too high. Other informal institutions such as patriotism or nationalism are not evolved to the extent of protection of the environment either. In the present form, informal institutions are not suitable to protect the environment from harm.

Measuring an environmental damage can be costly. Therefore, firms are not inclined to spend resources to determine the magnitude of the damage, let alone avoid it. If resources are not going to be used to protect it then why would someone even think to determine the magnitude of the harm to the environment. Instead, it is far more rational to ignore the problem. Cost minimizing and profit maximizing paradigms do not allow these kinds of expenditures. Even if consumers are willing to pay for the externalities, firms do not internalize the

externalities because they can use the willingness to pay to increase profits. Moreover, determining the true willingness to pay is difficult and requires high level of effort. Even if a firm were willing to internalize the cost to prevent damage, it has no control on the competing rivals who might not be willing to do the same, and put the firm at a disadvantage. Hence, it is natural to ignore the environmental damage from industrial and consumption activities.

Property rights have been proven to be very effective in the protection of private properties. Therefore, these could be an effective tool in the protection of the environment. However, it is impossible to develop individual property rights to the whole environmental medium, as it is cost-prohibitive. Even if the property ownership rights are assumed to have been assigned, enforcement is another impossible task. Allocating rights to stream and river segments would be very costly phenomenon. Water flow varies depending on the weather over which society has no control. The quality of water also changes over time. It is impossible to measure water quality for each household when hundreds of pollutants are present. As a result, the property rights have to deal with the changing conditions over time. Pollution enters streams and rivers, ends up in lakes and oceans. Assessing the damage to each property segment of rivers, streams, lakes and oceans would require significant societal resources. Enforcement cost of these ownership rights alone would likely exceed the benefits that can be had from the formation of these type of rights. Hence, property rights not only to oceans and lakes but also rivers and streams, have not evolved. They are not expected to emerge in near, even in the distance future without an occurrence of enormous environmental damage.

Similarly, division of the air is an impossible task given the changing direction, speed and pollutants. Continuous monitoring of the volume of air is not possible for each household let alone its protection from the various pollutants. For example, an individual could like his air cleaner than his neighbor. He would like to spend resources to keep it clean but the pollutants would cross boundaries

defeating his efforts to protect his property. Enforcement costs would be beyond the reach of the society, given that resources are needed for production of goods and services to satisfy other demands. Had it been feasible to divide air, the household would have protected their air just like they protect their other properties. However, the cost of enforcement is prohibitive in the formation of such institutions. Therefore, it is abundantly clear that the air pollution or for that matter climate change issues cannot be managed by the market mechanism where property rights are traded with nominal to no transaction costs. Institutional arrangements based on the property rights with respect to environments therefore does not seem to be a practical solution (for formation of institutions see North (1981)).

Accordingly, for protection of the environment, command and control mechanism is used. In the initial stage of environmental regulations, command and control has significant benefits compared to their cost. However, with the passage of time, benefits of regulations begin to recede and costs of these measure begin to increase. As a result, opposition of firms increases to these measures, and it becomes difficult to continue to justify them.

The internalization of externalities simply implies the incorporation of the social costs in the firms' production function. Firms would maximize their profits in the presence of environmental abatement costs. Benefits of regulatory controls are not the major concern of industry. However, uncertainty of the benefits of environmental amenities, which is quite common, is used by firms to oppose regulatory controls. The lack of property rights to the environment resulted in the absence of the market mechanism to trade these rights. If there were rights, they would have been traded in the market revealing the true cost of these rights and hence determining the value of benefits. In the absence of prices for estimating benefits, usually though not always, theoretical willingness to pay for environmental amenities is generated. However, it may be difficult to determine the willingness to pay because the public does not have the experience or habit of

creating such values. Because of limits of time, cognition, learning, adaptation, memory and emotional reaction to undue risks, willingness to pay is challenging to quantify.

To justify a regulation, cost and benefits are assessed. If the cost is lower than the benefits to society, it is deemed justified. On the other hand, if the cost is higher than the benefits then it is considered unjustified on economic grounds. Usually cost and benefit analysis is conducted on a social level. Winners and losers in general are not identified under this approach. In almost no cases, is the impact of a regulation on the value of the firm assessed. Our study is perhaps among the first to determine the impact of regulation on the value of individual firms in the United States.

One can expect a firm to incur cost to install technologies to comply with the regulatory requirements. It seems reasonable, therefore, to expect the firm to experience reduction in profits because it has expended resources for environmental amenities for the social good, but generally without a means to monetize the production of environmental amenities. Yet, a firm may not suffer losses in value if the public takes into account the regulatory cost when valuing its stock; public might be willing to pay for the regulatory costs indirectly. In this paper, we explore this phenomenon.

It is important to analyze the impact of regulatory costs on the value of the firm. One such approach that can be applied on the practical level is stock price analysis. Stock prices, among other factors, such as profits, keeps firms in business. If profits or stock price (expected value of the stream of profits), continue to go down due to environmental controls, investors will suffer losses, which means that the firm may cease to exist.

In order to minimize regulatory costs, a cap and trade program is used. It reduces the role of the command and control approach. The acid rain program for the power generating sector of the economy in the United States is an example

of such a program. The acid rain program affects electric generation facilities that emit SO₂ from burning fossil fuels to generate steam to run turbines for generation of electricity. This combines the market mechanism and the command and control approach to deal with SO₂ emissions. It provides an incentive to those firms that have low cost alternatives to control emissions and to sell extra allowances in the market to recover part of the cost of the remedial actions or to bank them for future use.

Burtraw (1996), and Ellerman and Montero (1998) analyze the SO₂ permit prices showing errors in expectations and existence of many compliance options increasing its price. Arimura (2002) studies the behavior of firms in coal producing states and the uncertainty of public utility commission regulations leading to fuel switching or blending, depressing SO₂ allowance price. Schennach (2000) presents theoretically the path of the SO₂ allowance price and SO₂ emissions. She analyzes the effect of changes in electricity demand, regulations, and control technologies on SO₂ price. She demonstrates in her model that SO₂ expected price is increasing at the rate of interest under certainty, but less than that under uncertainty. Carlson et al (2000) compare the cost savings from fuel switching with the SO₂ trading program and command and control approach for the electric generating utilities in the United States, demonstrating that gains from trading are overestimated. Chestnut and Mills (2005) estimate the health benefits of the acid program associated with SO₂ reduction. Kosobud et al, (2005), by using time series data, show that SO₂ permit stock has a positive rate of return. They find no relationship between return on SO₂ permit and the return on NASDAQ, S&P 500, the Russel 2000 and 3000, and even gold and treasury bills. Ellerman and Montero (2007) show that banked SO₂ permits are efficient. Helfand et al. (2007) analyze SO₂ permit price change as a function of consumer price index, natural gas price, risk free interest rate, and excess return in stock market in the presence of structural breaks in the series. Without structural breaks, they demonstrate, it depends upon wages and industrial

production as well as natural gas price, interest rate and excess return. Boutabba et al. (2012) present the dynamics of the SO₂ spot price time series, using a cointegration approach. This brief review shows that most of the studies are focused on the behavior of SO₂ price. Kahn and Knittel (2002) conclude that stock price of electric companies did not fall in view of the of the Clean Air Act Amendment proposal in 1989, using the event study approach. Linn (2010) uses the change in stock price of electric companies in various regions to determine the expected reduction in profits of firms, in anticipation of a regional cap-and-trade program for nitrogen oxides, using the event study methodology. Again, this shows there is no study in the literature that has analyzed the impact of SO₂ permit price on firm's stock price in the United States, without the use of event study approach. To bridge this gap, we determine the impact of SO₂ price on the stock price of a firm, which is an important barometer of a firm's value. This study does not use the event study methodology, because it is not a speculative study. We opt for the micro level behavior estimating functional relationship of each firm separately. We do not aggregate data because some of the firms' variation could offset the effect of other firms' variations in estimating the impact of the SO₂ permit price. Our objective is to assess the impact of the regulatory cost on a firm. Cost of the regulatory controls could be affecting the electric generating firms adversely. If the regulation has significant negative effect on its stock (discounted stream of profits) it would imply that the firm is worse off. On the other hand, if it has positive effect on its stock, then the firm is better off due to a well-designed cap and trade program. A firm could become more efficient in the long run because of the change in the production process triggered by a well-designed regulation, which could offset at least part of the regulatory cost, according to the Porter hypothesis (see Ambec, et. al (2013)). A firm might be able to transfer the entire cost or a part of it onto the ultimate users because of the inelastic demand for electricity, leaving its stock price unaffected. Thus, SO₂ price impact analysis would be useful for designing policies regarding

cap and trade and other similar programs effecting the stock prices of firms or the stream of profits. To analyze this phenomenon, we use the time series data related to SO₂ allowance price (hereafter SO₂ cost or price).

In the balance of the paper, we present models in section 2, data and testing of the time series in section 3, and discussion in section 4. The conclusions are presented in section 5.

2 Models

For time series data analysis, the Box and Jenkins framework is used. The autoregressive (AR), moving average (MA), and autoregressive integrated moving average process are employed for explaining stochastic processes. If unit root is present, then the nonstationary version of the model is used. Nonstationary time series cannot be analyzed by the ordinary least squares technique or maximum likelihood function because it can show significant relationship when none exists. Granger and Newbold (1976) created two independent random walk time series and used the regression approach. They showed that ordinary regression produced a strong relationship between the series when in fact none existed. Stock market time series are usually nonstationary. Moreover, the stock prices fluctuate significantly, varying the mean, due to daily news. To explain the behavior of the stock market, Engle (1982) developed an autoregressive conditional heteroscedasticity model (ARCH). The variance of the stock market time series is not constant; it is a function of time because day-to-day good or bad news affects it. Bollerslev (1986) extended the model by applying the autoregressive structure to the variance expression in the generalized autoregressive conditional heteroskedastic model (GARCH). These types of models or some variation of them has been used for stock market analysis. However, Ali (2011, 2013) pioneered their use in the environmental literature.

Autoregressive and thereby GARCH models are important because they seem to reduce the need for exogenous variables because the lagged values of the dependent variable become exogenous variables which as a proxy represent other relevant variables. Thus, they might not create a serious omitted variable problem. Moreover, if there is only one variable which cannot be explained adequately in ordinary regression set up, these models can still provide a reasonable explanation because of lagged values and the coefficients of the variance equation. In addition, these models are better suited for forecasting.

2.1 Autoregressive with Exogenous Variables

An autoregressive with exogenous variables (ARX) model is presented as

$$y_t = \phi(l)y_t + \beta x_t + \varepsilon_t. \quad (1)$$

Here y represents the dependent variable and x represents exogenous variables with ϕ and β coefficients while ε represents an error term, l time lag and t indicates time period.

2.2 Moving Average with Exogenous Variables

Moving average process is simply expressed as

$$y_t = \beta x_t + \theta(l)\varepsilon_t \quad (2)$$

with θ representing the coefficient of the moving average part.

2.3 Autoregressive Moving Average with Exogenous Variables (ARMAX)

This process combines AR and MA processes together. Its expression is

$$y_t = \phi(l)y_t + \beta x_t + \theta(l)\varepsilon_t. \quad (3)$$

The autoregressive integrated moving average with exogenous variables (ARIMAX) is an autoregressive moving average (ARMA) process with the differenced variables to deal with the nonstationarity condition when exists. Using the difference operator (Δ) it is specified by

$$y_t = \phi(L)\Delta y_t + \beta x_t + \theta(L)\varepsilon_t. \quad (4)$$

2.4 ARCH Model

This model begins with the AR specification differing in the error structure

$$y_t = \phi(L)y_t + u_t. \quad (5)$$

This model relaxes the assumption of the error term making it a function of the standard deviation. The error structure of the model with standard deviation is

$$u_t = \sigma_t \varepsilon_t, \quad u_t = \varepsilon_t \sqrt{\alpha_0 + \alpha_1 u_{t-1}^2 + \alpha_2 u_{t-2}^2 + \dots + \alpha_q u_{t-q}^2}. \quad (6)$$

The residuals from the regression are used to estimate the ARCH coefficients (α).

2.5 GARCH Model

Generalized autoregressive conditional heteroscedasticity (GARCH) is similar to ARCH differing only in the variance structure which is specified as

$$\sigma_t^2 = \beta_0 + \beta(L)\sigma_t^2 + \alpha(L)u_t^2 \quad (7)$$

ARCH and GARCH take into account the volatility of the stock market by using the deviation from the mean in previous periods in estimating the parameters of the process.

3 Data Explanation

3.1 Data

For the cost of regulation of the power generating industry, we used the emission allowance price of SO₂. SO₂ prices reflect the control cost of the technology or other measures to comply with the cap and trade program employed to control SO₂ emissions. We use the cost of the allowance as a surrogate for the cost of the regulation of the power industry. At the time of the issuance of the regulation, cost benefit analysis is usually carried out that predicts the impact of the

regulation in the future. It is not the actual cost of the regulation (reflected by the firms themselves). Moreover, it is a static model in partial equilibrium framework where adjustment takes place instantly. To reflect reality, we used the market based price determination of the regulatory regime.

Our study is focused on the monthly stock price of firms and SO₂ trading price, which are key variables to estimate the impact of regulation on the value of the firms. If the regulatory cost is significant, it is expected to depress the stock price of a firm. However, if the public is willing to pay for the environmental control cost, it might not affect the stock price. We hypothesize that the SO₂ price will have negative impact on the stock value if the investing public is unwilling to pay for the environmental control costs. However, it should have no effect if the public is compensating the firms through the stock price for the expenditure related to the regulation on emissions. If this approach is successful, we expect the researcher to conduct similar studies in the environmental field using time series cost data. Kahn and Knittle (2003) and Linn (2010) used the stock price change as the effect of the news of the Clean Air Amendment June, 1989 proposal, using the event study approach. We think that ARCH/GARCH are suitable to determine the impact on the stock price of a firm or the stream of profits. Ironically these models have not been used often, although they are developed for the stock price analysis. Since SO₂ permits trading is not a onetime phenomenon, event study approach is not appropriate. Similarly, SO₂ credit exchange is not one-time phenomenon. Moreover, SO₂ permit price cannot be anticipated exactly beforehand, therefore event study approach is not applied. We use the ARCH/GARCH model to determine the effect of the SO₂ price on the stock price of firms or the discounted stream of profits.

Our data set consists of the monthly time series of stock prices of firms, SO₂ allowance price series as well as time series of coal, natural gas and electricity prices from 1997 to 2007. We used the same SO₂ spot market price monthly time series which was used by Boutabba et al (2012) to explain the dynamics of

the SO₂ price since trading in the United States. We could not use the data for 1995 and 1996 for SO₂ because natural gas price was not easily available for this time period. We did not include the latest observations of SO₂ allowance price because of the structural break in the series due to a completely collapsed market. Since these firms are large having operations in various parts of the country generally, we used the U.S. level data and constructed the prices time series of the natural gas, coal and electricity from the reports of the Energy Information Administration, Department of Energy. Company specific information was not readily available. For certain time periods, monthly data for coal and natural gas was found to be missing. Therefore, we extrapolated it to fill the monthly data gaps employing R and SAS software using annual or semiannual data.

The Natural Resources Defense Council presented the emission data for 100 largest emission producing companies in the United States (NRDC (2014)). We initially selected the top 10 companies (without Tennessee Valley Authority) to analyze the impact of SO₂ allowance price on the stock price of these companies. We did not select Tennessee Valley Authority because it was not a private company. Moreover, if data was not easily available for a company we dropped it from consideration. Duke Energy, Exelon, Southern, NextEra, American Electric Power (AEP), Calpine, FirstEnergy, Dominion, Pennsylvania Power and Light (PPL) and Entergy were the initial set, used as a starting point of investigation. However, FirstEnergy and Calpine were found to be too new to have complete time series data, therefore, we dropped them from the set. Instead we added Public Service Enterprise Group (PSEG) because of ease of availability of historical time series data for it. As a result, for the final analysis, we were left with a sample of nine companies. The historical time series of stock prices were taken or constructed from Yahoo finance website. It is a rather difficult task to deal with individual companies because each company might be facing circumstances that are different from others. As a result, contradictions could arise in the analysis.

3.2 Augmented Dicky Fuller Test

To choose the appropriate model for establishing functional relationships, a stock price series needs to be tested for the existence of unit root. Unit root arises if the series is nonstationary. For test purposes, we use an augmented Dickey Fuller (ADF) test. This test uses the lagged and a differenced variable in the test equation. If the series is nonstationary, then in the presence of a differenced variable, the lagged variable will show no explanatory power. Its coefficient would be no different from zero. On the opposite, if the coefficient is nonzero, it implies that the series is stationary. If the test statistic (τ) is smaller than the critical value, then null of unit root, $\phi = 1$, is rejected. On the contrary, if τ is greater than the critical value, alternative hypothesis, $\phi < 1$, is rejected. If $\phi > 1$ then the process is explosive which usually is not modeled because it is not very realistic. The logic of the test is to assess if a series contains a random walk process which could be an issue with respect to time series data. The random walk reduces to the sum of the white noise (the coefficient ϕ of the lagged response variable is simply 1). We test the series with and without the trend parameters along with the constant.

In terms of the p value, if the probability is below the five percent threshold, we reject the null hypothesis. However, if the probability is greater the 5 percent threshold we accept the existence of the unit root. We conducted the ADF test with lag 1 including first the constant in its specification, for the stock price time series of each firm. Interestingly, the p values are found to be above the threshold, implying that the time series of not only of Duke, Exelon, and Southern, but also AEP are nonstationary, thus τ values fell beyond the threshold. Similarly, the p value failed to reject the null for Entergy, Dominion, AEP and PSEG. NextEra is exception to the rule. The SO₂ series is also found to be nonstationary. Since we had hypothesized the time series to be nonstationary, a uniform support for the null hypothesis is a remarkable discovery.

The test statistic changes if the trend parameter is included in the test equation. Therefore, we tested each series not only with a constant but also with a trend and constant in the specification of the equation. This too failed to reject the null hypothesis. One by one each series is shown to be nonstationary. The test results are presented in Table I.

3.3 Kwiatkowski–Phillips–Schmidt–Shin (KPSS) Test

An alternative to the ADF test for the unit root is Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. This test is opposite to the ADF test in the specification of the null hypothesis; it has stationarity as the null hypothesis instead of the unit root. It is based on the regression on a constant. It tests the variance of the error terms ε as $\hat{\sigma} = 0$ against $\hat{\sigma} > 0$. Residuals are used to estimate the variance. If the process is a random walk, then $\hat{\sigma} > 0$. If no random walk, then there must exist a constant implying $\hat{\sigma} = 0$. We used this test to confirm the nonstationary property of the stock series. KPSS too rejected the null, validating the nonstationarity of time series without a trend, except NextEra. For NextEra, the test failed to reject the null (stationarity) at a 10 percent significant level, but at a 5 percent level it reversed the conclusion. Nevertheless, test statistic (0.432) is close to the rejection border (0.465) at a 5 percent level. KPSS also validated SO₂ series to be nonstationary. The results for stock prices are presented in table I.

Table I: ADF and KPSS Tests with and without Trend

Name of Firm (stock price)	With Constant			With Constant and Trend		
	ADF Test Statistics (τ)	<i>P</i> Value	KPSS Test Statistics	ADF Test Statistics (τ)	<i>P</i> Value	KPSS Test Statistics
Duke	-2.6343	0.0860	1.7183	-3.1619	0.0922	0.1653
Exelon	-2.2020	0.2057	2.9333	-2.7165	0.2297	0.6937
Southern	-1.5350	0.516	4.1371	-3.1817	0.0881	0.3987
NextEra	-3.0626	0.0295	0.4321	-3.0799	0.1111	0.4338
AEP	-1.9035	0.331	2.0733	-1.9076	0.6505	0.3390
Entergy	1.2454	0.9985	5.6176	-1.5607	0.8084	1.0079
Dominion	-0.7151	0.8412	5.2395	-3.3359	0.0605	0.1946
PPL	-2.4532	0.1273	2.8087	-2.9014	0.1619	0.3825
PSEG	-0.7848	0.8229	3.9473	-2.1147	0.537	0.6264

All the estimated values, except for NextEra, are greater than the critical values at a 5 percent significant level to reflect nonstationarity of the series. This is reversal of the usual testing which causes confusion in hypothesis testing; more negative value means evidence against the null (greater the negative number, greater the evidence against the null).

We also included the time trend in testing. This time the KPSS test uniformly rejected the stationarity, confirming the existence of unit root in the time series because test statistics fell above the critical value (0.148). To make a cursory judgement about the trend, we included the time trend in the GARCH model, but it was not found to be a significant variable. Accordingly, we ignore it. Our focus in this paper is to determine the impact of SO₂; the determination of a time trend, stochastic or otherwise, is not germane to this study. We have to difference the stock price series (proxy to stock return) for modeling.

4 Discussion

4.1 ARCH/GARCH Model

We employ the GARCH Model to estimate the functional relationship. This is usually used to analyze stock prices. We maximize the information criteria to determine a functional relationship. The lag order at which the criteria are maximized for the estimation of parameters is very important for the model. We use a lag of one for the GARCH model.

4.2 Functional Relationship

In determining the effect of the SO₂ prices on stock prices, we tested variables such as the price of electricity, the price of natural gas, and the price of coal. For model specification for estimating a functional relationship, at the outset we need to determine the existence of nonstationarity in the data. To explore the existence of nonstationarity which is usually problem in the economic time series data, we applied two different tests, ADF and KPSS. The ADF test statistics fell below the critical value implying that not only SO₂, coal and natural gas price but also electricity price is nonstationary series. On the contrary, the KPSS test statistics exceeded the critical value, falling in the rejection region, ruling out stationarity. In KPSS testing, critical values with and without trend are invariant (respectively 0.148 and 0.465), which failed to back up the null hypothesis. Thus, both the tests supported each other's conclusion. We establish that all the series are nonstationary. The output is presented in Table II. It is important to point out that the ARCH and GARCH models are for stationary, not for nonstationary time series. Therefore, we need to difference the variables to stationarize the series for modeling.

Table II: ADF and KPSS Tests with and without Trend

Price	With Constant			With Constant and Trend		
	ADF Test Statistics (τ)	P Value	KPSS Test Statistics	ADF Test Statistics (τ)	P Value	KPSS Test Statistics
SO2	-2.07578	0.2547	3.4365	-2.9508	0.1464	0.7348
Coal	-0.3635	0.9129	3.7500	-1.9930	0.6046	1.2597
Natural Gas	-1.9091	0.3284	3.8964	-3.1751	0.0894	0.1870
Electricity	-2.5090	0.1132	5.3036	-5.6245	0.0000	1.1207

All the estimated values are greater than the critical values at a 5 percent significant level to reflect nonstationarity of the series. This is usual hypothesis testing; greater the value the greater evidence against the null.

Coal price is not found to be a significant variable for any of the firms. Coal seems to be neutral to the stock price of the firms. This was expected because coal is being replaced with natural gas. And it is not a preferred input irrespective of its price. Conversely, natural gas is a significant variable only for one firm, with positive sign of its coefficient. This too is not surprising because the price of natural gas seems to have increased during 1996 to 1997 time period, resulting in the positive sign for its coefficient (see EIA (2007)). Natural gas is increasingly being used because of the low emissions of the pollutants during combustion. To generate allowances natural gas is very important, along with scrubbers and fuel mix or fuel switching. The model output supports a generalized conclusion that coal and natural gas prices are not affecting stock prices of firms significantly. This is partly due to the fact, that coal and gas contracts are not negotiated on a short-term basis. They are negotiated instead on the long-term basis. Therefore, short-term variations in the market do not affect generators significantly. Thus, the model seems to yield results consistent with the economic theory.

However, price analysis of coal and natural gas is not the focus of this study. The main purpose of the study is to assess the impact of SO₂ price on the stock value of firms. Even in this case, the model output does not reflect that the SO₂ is significant variable for any of the equations. This too suggests that the SO₂ price variation is not affecting stock prices of the firms.

The SO₂ variable seems to be neutral to the stock value of the firms. This is a remarkable discovery, which seems to be reasonable. It is consistent with the results of the studies pointing out that allowances prices are significantly lower than was anticipated in the beginning of the SO₂ program, because of innovations in the air emission control technologies (see Chan et. al (2012)). The price of wet scrubber technology which is highly effective (above 90 percent removal efficiency) in reducing SO₂ emissions has come down dramatically. Thus, investors probably deemed its cost just a part of the regular expense of generating electricity without adversely affecting the stock prices of the firms. The model output, which uniformly rejects the hypothesis of negative effect, is presented in the Table III. We also used the stock return as the response variable, which also yielded results consistent with the above analysis. This is because the differenced stock price variable and stock return are not very different from each other.

Table III: GARCH (1,1)/ARCH (1) with Exogenous Variables

d_Duke Stock Price				
Variable	Coefficient	Standard error	Z	P-value
Constant	0.1951	0.2135	0.9138	0.3608
d_ SO ₂ price	0.0000	0.0021	0.0114	0.9909
d_Natural gas price	0.1930	0.1773	1.0887	0.2763
d_Coal price	-2.4508	3.8839	-0.6310	0.5280
d_Electricity price	-2.6928	6.4186	-0.4195	0.6748

alpha(0)	0.5913	0.7224	0.8186	0.4130
alpha(1)	0.1201	0.0978	1.2281	0.2194
beta(1)	0.7267	0.2377	3.0571	0.0022***
Log-likelihood	-245.2577		Akaike criterion	508.5154
Schwarz criterion	533.5275		Hannan-Quinn	518.6720
d_Exelon Stock Price				
Constant	0.0612	0.4483	0.1365	0.8914
d_SO2 price	-0.0028	0.0052	-0.5413	0.5883
d_Natural gas price	0.0584	0.3831	0.1525	0.8788
d_Coal price	-0.8230	8.3477	-0.0986	0.9215
d_Electricity price	14.0346	14.8445	0.9454	0.3444
alpha(0)	14.7952	1.94005	7.6262	<0.00001***
alpha(1)	0.0024	0.02088	0.1155	0.9080
Log-likelihood	-329.3045		Akaike criterion	674.6090
Schwarz criterion	696.8420		Hannan-Quinn	683.6371
d_Southern Stock Price				
Constant	0.1355	0.1025	1.3217	0.1863
d_SO ₂ Price	0.0024	0.0014	1.7500	0.0801*
d_Natural gas price	-0.0028	0.0944	-0.0299	0.9762
d_Coal price	-4.2109	2.3755	-1.7726	0.0763*
d_Electricity price	0.4869	3.7793	0.1288	0.8975
alpha(0)	0.2500	0.4138	0.6043	0.5457
alpha(1)	0.6060	0.4563	1.3280	0.1842
beta(1)	0.3940	0.5296	0.7440	0.4569

Log-likelihood	-195.0132		Akaike criterion	408.0264
Schwarz criterion	433.0386		Hannan-Quinn	418.1831
d_NextEra Stock Price				
Constant	0.4183	0.2894	1.4452	0.1484
d_ SO ₂ Price	-0.0008	0.0022	-0.3493	0.7269
d_Natural gas price	0.1820	0.1948	0.9344	0.3501
d_Coal price	3.7353	4.9181	0.7595	0.4476
d_Electricity price	-22.2277	11.5506	-1.9244	0.0543*
d_AEP Stock Price				
alpha(0)	1.4064	1.0610	1.3256	0.1850
alpha(1)	0.6270	0.1945	3.2239	0.0013****
beta(1)	0.3730	0.1054	3.5385	0.0004****
d_AEP Stock Price				
Log-likelihood	-292.4742		Akaike criterion	602.9483
Schwarz criterion	627.9605		Hannan-Quinn	613.1050
d_AEP Stock Price				
Constant	0.1200	0.2437	0.4924	0.6224
d_ SO ₂ price	0.0017	0.0019	0.9249	0.3550
d_Natural gas price	0.0489	0.1497	0.3266	0.7439
d_Coal price	-4.1896	4.2839	-0.9780	0.3281
d_Electricity price	3.1946	6.0102	0.5315	0.5950
d_AEP Stock Price				
Alpha(0)	0.3812	0.2786	1.3683	0.1712
Alpha(1)	0.2701	0.1098	2.4587	0.0139**
Beta(1)	0.6671	0.1141	5.8462	<0.00001***
d_AEP Stock Price				
Log-likelihood	-249.0009		Akaike criterion	516.0017
Schwarz criterion	541.0139		Hannan-Quinn	526.1584

d_Entergy Stock Price				
Constant	0.3656	0.2181	1.6765	0.0936*
d_SO2 price	-0.0004	0.0027	-0.1386	0.8897
d_Natural gas price	0.0756	0.2306	0.3279	0.7430
d_Coal price	-2.7102	3.4723	-0.7805	0.4351
d_Electricity price	13.2275	7.2298	1.8296	0.0673*
alpha(0)	2.9153	0.5123	5.6905	<0.00001***
alpha(1)	0.2425	0.1345	1.8029	0.0714*
Log-likelihood	-246.2258		Akaike criterion	508.4515
Schwarz criterion	530.6845		Hannan-Quinn	517.4797
d_Dominion Stock Price				
Constant	0.3230	0.2322	1.3907	0.1643
d_SO2 price	0.0022	0.0032	0.6859	0.4928
d_Natural gas price	0.5739	0.2172	2.6417	0.0083****
d_Coal price	-3.9752	4.1584	-0.9560	0.3391
d_Electricity price	7.7310	7.8438	0.9856	0.3243
alpha(0)	2.4773	1.1071	2.2376	0.0252**
alpha(1)	0.4398	0.2308	1.9055	0.0567*
beta(1)	0.1907	0.2296	0.8386	0.4062
Log-likelihood	-267.1824		Akaike criterion	552.3648
Schwarz criterion	577.3769		Hannan-Quinn	562.5214
d_PPL Stock Price				
Constant	0.2905	0.2097	1.3851	0.1660
d_SO2 price	0.0008	0.0024	0.3470	0.7286

d_Natural gas price	-0.0943	0.1882	-0.5011	0.6163
d_Coal price	-2.2847	3.4061	-0.6708	0.5024
d_Electricity price	12.2277	5.3488	2.2861	0.0223**
alpha(0)	1.6601	0.5156	3.2196	0.0013***
alpha(1)	0.8522	0.2064	4.1284	0.0000***
beta(1)	0.1478	0.0725	2.0382	0.0415**
Log-likelihood	-273.1641		Akaike criterion	564.3283
Schwarz criterion	589.3404		Hannan-Quinn	574.4849
d_PSEG Stock Price				
Constant	0.1847	0.2449	0.7542	0.4507
d_SO ₂ price	0.0017	0.0038	0.4302	0.6670
d_Natural gas price	0.0780	0.2346	0.3325	0.7395
d_Coal price	-0.0813	3.9700	-0.0205	0.9837
d_Electricity price	13.1434	8.6228	1.5243	0.1274
alpha(0)	1.6491	1.0751	1.5339	0.1251
alpha(1)	0.2881	0.1883	1.5296	0.1261
beta(1)	0.4406	0.2738	1.6093	0.1076
Log-likelihood	-266.1273		Akaike criterion	550.2546
Schwarz criterion	575.2667		Hannan-Quinn	560.4113

Small d indicates the differenced variable such as d_{SO_2} or d_{Duke} stock price. Asterisk in the last column indicate the level of significance; greater the number of asterisk the greater is the significance of the variable in terms of low p value.

4.3 ARIMAX Output

For the above analysis, GARCH included the autoregressive and moving average components in the specification of the variance process. Here we relax this assumption. Our purpose is to verify if an alternative model also would produce the similar results. If this happens, it will provide additional support to the above reached neutrality conclusion. For verification, we employ an autoregressive integrated moving average (ARIMA) model, which is used for the nonstationary time series. The ARIMA (p, d, q) is an ARMA (p, q) for stationary time series. It must be pointed out that the ARMA model reduces the need for other exogenous variables because the lagged value of the dependent variable as an exogenous variable represent the left out variables; the impact of other variables is assumed to be represented by the lagged values.

We used ARIMAX (1,1,1) in estimation. Once again, we reached an interesting result. Only in one case, natural gas coefficient seems to be significant even though the p value is not mathematically below the rejection threshold (p values, 0.0503 at 5 percent significant level). Strictly interpreting the p value, none of the coefficients is different from zero in any of the equations. Thus, ARIMAX model also supports the neutrality hypothesis. The results do fit our expectation. Therefore, we generalize that the stock prices are not affected by the SO_2 prices. To avoid crowding of the paper, and not to burden the reader with excessive statistics, we do not present the ARIMAX (1,1,1) output.

On the basis of the model results, now we theorize that the public does not consider these variables to be influential when it is valuing the stock prices. It does not seem to downgrade this industry as far as the stock price is concerned because of SO_2 cost. This is a radical finding. However, we have to determine

if it holds true in an alternative model that also deals with the nonstationary variables. This is explained further.

4.4 GARCH Model without Exogenous Variables

In the final analysis, since the exogenous variables were insignificant we drop them from consideration for the SO₂ impact analysis on firms' stocks. To be almost sure about the reasonableness of our impact analysis of the SO₂, we supplement the analysis with the use of GARCH focusing on the SO₂ permit cost independent of coal, natural gas, and electricity prices. It is important to point out that it is not our purpose to predict stock prices of the firms. Our objective is limited to determining only if the SO₂ price variable has any effect on stock price. Therefore, we are not including other macroeconomic variables, in part due to the lagged variable already includes the effect of other variables. If the results still hold in the alternative model, then we will conclude that SO₂ in general is neutral in affecting the value of most of the firms. Resultantly, we could theorize that the public indirectly pays for the environmental costs anyway.

Ultimately, we ran the GARCH model between the stock prices of firms and the SO₂ cost time series which was our main purpose. The coefficients of the variance equations are significant with a few exceptions. This highlights that the variance equation is significant for most of the firms. *P* values fall below the 5 percent threshold level for most of the parameters of the variance expression. In contrast, *p* values exceeded the critical values for SO₂ coefficients. More importantly, the SO₂ coefficient is insignificant for all of the firms except Exelon; there is not even a firm for which it was not different from zero. The model could not run for Exelon because the variance matrix was not positive definite. However, we have enough information from the AR model to rule out the significance of SO₂. Remarkable consistency of the SO₂ results highlights that the SO₂ allowance price is neutral to the stock price of the firms. This conclusion is similar to the conclusion of no impact reached by Khan and Knittle

(2002) in an anticipation of the Clean Air Amendment in 1989 for No_x . It could be expected because the demand for electricity is inelastic. The public expects the cost to be passed on to consumers anyway, not to affect the profits of the firms significantly. The model output is presented in Table IV.

Table IV: GARCH (0,1)/ARCH (1) Model Output

d_ Duke Stock Price				
	<i>Coefficient</i>	<i>Std. Error</i>	<i>Z</i>	<i>p-value</i>
Constant	0.1110	0.1799	0.6173	0.5370
d_SO ₂ price	0.0003	0.0025	0.1274	0.8986
d_ Southern Stock Price				
alpha(0)	3.6037	0.5489	6.5652	<0.00001
alpha(1)	0.0412	0.0843	0.4887	0.6251
Log-likelihood	-247.5233		Akaike criterion	505.0467
Schwarz criterion	518.9423		Hannan-Quinn	510.6892
d_ NextEra Stock Price				
Constant	0.1503	0.0840	1.7892	0.0736*
d_SO ₂ price	0.0021	0.0013	1.6788	0.0932*
alpha(0)	0.7412	0.1653	4.4847	<0.00001***
alpha(1)	0.9512	0.2784	3.4174	0.0006***
Log-likelihood	-194.2180		Akaike criterion	398.4359
Schwarz criterion	412.3316		Hannan-Quinn	404.0785
Constant	55.4443	0.4308	128.6970	<0.00001***
d_SO ₂ Price	0.0009	0.0106	0.0844	0.9327

alpha(0)	4.0521	1.9459	2.0823	0.0373**
alpha(1)	1	0.1671	5.9836	<0.00001***
d_AEP Stock Price				
Log-likelihood	-396.7964		Akaike criterion	803.5928
Schwarz criterion	817.4884		Hannan-Quinn	809.2353
Constant	35.2113	0.6115	57.5773	<0.00001***
d_ SO ₂ price	0.0025	0.0029	0.8577	0.3910
alpha(0)	2.2699	1.0425	2.1774	0.0295**
alpha(1)	1	0.166686	5.9993	<0.00001***
Log-likelihood	-366.3156		Akaike criterion	742.6312
Schwarz criterion	756.5268		Hannan-Quinn	748.2737
d_Energy Stock Price				
Constant	0.5490	0.1893	2.8993	0.0037***
d_ SO ₂ price	.00009	0.0025	0.0338	0.9730
alpha(0)	3.1298	0.5432	5.7615	<0.0001***
alpha(1)	0.1981	0.1266	1.5646	0.1177
Log-likelihood	-248.0784		Akaike criterion	506.1567
Schwarz criterion	520.0523		Hannan-Quinn	511.7993
d_Dominion Stock Price				
Constant	0.3715	0.2003	1.8552	0.0636*
d_ SO ₂ price	0.0052	0.0034	1.5483	0.1216

alpha(0)	3.7996	0.7724	4.9189	<0.00001***
alpha(1)	0.4224	0.1990	2.1222	0.0338**
Log-likelihood	-271.3047		Akaike criterion	552.6094
Schwarz criterion	566.5050		Hannan-Quinn	558.2520
d_PPL Stock Price				
Constant	0.5782	0.1857	3.1141	0.0019***
d_SO ₂ price	0.0001	0.0023	0.0514	0.9590
alpha(0)	2.8810	0.5897	4.8853	<0.00001***
alpha(1)	0.9412	0.2441	3.8562	0.0001***
Log-likelihood	-276.5142		Akaike criterion	563.0283
Schwarz criterion	576.9239		Hannan-Quinn	568.6709
d_PSEG Stock Price				
Constant	0.4149	0.2133	1.9448	0.0518*
d_SO ₂ price	0.0035	0.0029	1.1854	0.2359
alpha(0)	3.7616	0.7814	4.8137	<0.00001***
alpha(1)	0.3698	0.2008	1.8417	0.0655*
Log-likelihood	-267.5561		Akaike criterion	545.1122
Schwarz criterion	559.0079		Hannan-Quinn	550.7548

Small d indicates the differenced variable such as d_SO₂ or d_Duke stock price.

Researchers should consider focusing on the assessment of the impact of the cost of regulations in air and water on the value of firms that generate electricity. Regulations requiring point sources to use best technology to control pollution of water and rules for stationary sources to control emission into air might be candidates for such analyses. Cost benefits alone are not sufficient to assess the

impact of regulations. Cost benefit analysis is important for justification of regulations but is not relevant to determine the impact on the stock price of firms which really matters to shareholders. It might be useful to determine whether or not internalization of cost of the controls has any impact on the stock of the firms. It is possible that society, directly or indirectly, is paying for it anyway. Perhaps the public is not riding free. Additional research is warranted in this area.

5 Conclusion

Property rights might be the least cost institution to protect personal property. However, the evolution of the property rights does not exist for the environment. Development of workable ownership rights to the environment is an impossible task. Even if these rights are assumed to be developed, their enforcement would be very costly. In theory, the benefits probably do not supersede the cost of such arrangements. Market mechanism is another least cost institution to produce and exchange goods and services. However, market mechanism's imperfection imposes serious damage to the environment. Industrial activities to produce goods affect environments adversely. The cost of such externalities is not internalized by the market mechanism. Attempts to internalize externalities through regulations are usually opposed by the firms because they are considered to affect them. Cost benefit analysis is carried out to assess the justification of the regulation regimes to protect environments. If the benefits are greater than the cost, a regulation is justified. However, if the cost is higher than the benefits, then the regulation is deemed unjustified. Cost benefit analysis is a static analysis. Changes are assumed to take place instantly, which is very unrealistic. Moreover, the cost benefit analysis does not determine the impact on stock price of the firms. Nor is the cost benefit analysis carried out in determining the impact of regulatory directives or requirements on the value of the firm. Our study is likely to be among the first to determine the impact of a regulation on the

stock price of a firm.

We hypothesized initially that the cost of the regulation would have a negative effect on the stock price. To test this hypothesis, we selected 10 major SO₂ emission generating firms. After some investigation, we were left with nine firms' data in the United States in the power generation sector. We used time series data with respect to prices of firms' stocks, SO₂ allowance, coal, natural gas, and electricity. Our object was to assess the impact (the sign and significance) of the coefficient of the SO₂ variable. We tested the time series of the SO₂ and stock price to determine if there exists a unit root which could be problem for such series. Augmented Dicky Fuller unit root and KPSS tests show that the series are nonstationary. Day to day, not only positive but also the negative news, affects stock prices. Taking into account such phenomenon requires the specification of a dynamic process. Therefore, we used the generalized conditional heteroscedasticity model. This model is primarily developed for time series of prices of stocks. Ali (2011), initially introduced the use of GARCH models in the environmental field. Subsequently, Ali (2013) introduced variations of GARCH models in the same field.

Likely, our study is among the first, if not the first, to determine the impact of the environmental cost on the stock prices. We hypothesize that if the public is unwilling to pay for the environmental protection cost, the price of the SO₂ allowance would have a negative effect on the stock price. It will dampen the price of stock. On the other hand, if the public is willing to pay for the cost, it will have no impact on the stock price of firms. Similarly, coal price will have negative impact on the stock prices of firms in the presence of the natural gas price variable in the equation. We found that these variables are statistically insignificant for almost all of the firms. This result was also confirmed by the output of autoregressive integrated moving average model with exogenous variables. Therefore, we dropped coal, natural gas, and electricity price variables from the functional relationship. Finally, we estimated a functional relationship

between the stock price and the SO₂ price. This time the SO₂ price was found to be uniformly neutral (insignificant) in its impact on the value of the firm. The model output rejected the null of negative impact on the environmental control cost. This is a rather striking conclusion of this study. Further research is needed on this issue. We suggest environmental economists determine the effect on the value of the firms of the environmental control cost in the area of air and water, using time series data.

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