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Abstract

This paper examines the effect of the Fukushima nuclear accident on stock returns of Japanese electric power companies by using a panel data analysis. By the fixed-effects panel data analysis, we estimate each company's individual effect on the intercept and the coefficient associated with the market return. In the analysis we introduce two structural change points of the Fukushima accident and so-called *Abenomics* economic policies under which Japanese stock markets were vitalized. Following Kawashima and Takeda (2012), we also examine whether or not the accident affected more sharply companies owning nuclear power plants, companies with a major commitment of nuclear power generation, and companies owning the same type of nuclear power reactors as the one operated at the Fukushima Daiichi station.

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1 Introduction

The Fukushima nuclear accident is one of the worst nuclear accidents in the world. Damages by the accident have been enormous economically and socially and recovering from the accident is still slow. Steps to control the Fukushima Daiichi nuclear power stations are taken but they require meticulous care. On the other hand, a number of nuclear power plants are planned to be constructed in the future all over the world. Thus we consider it important to evaluate consequences of the Fukushima nuclear disaster. There exist a number of studies examining the effect of the Fukushima nuclear disaster on stock prices of electric power companies (Betzer et al. (2011), Ferstl et al. (2012), Kawashima and Takeda (2012), Lopatta and Kaspereit (2012), and Serita and Xu (2012) among others). They report significantly negative effects on Japanese electric power companies in periods of the first couple of days and subsequent several months after the disaster. In this study we aim to investigate the effect of the Fukushima nuclear accident on stock returns of Japanese electric power companies using a fixed-effects panel data analysis. By the fixed-effects panel data analysis, we can estimate an individual effect of each eletric power company in the intercept and coefficient associated with the market return along with effects of other explanatory variables. In order to estimate the fixed-effects model of stock returns of electric power companies, we have tried several methods to estimate variances of estimates in models we analyze. We have found clustering in residuals for the same company so that only t-values obtained using cluster-robust variances taking into account correlation of the residuals of the same company appear to produce reasonable values.

After the accident, many events occured in Japan. However, in this study we try to incorporate only two long-lasting important events, i.e., the effects of the Fukushima accident and the effects of so-called *Abenomics* economic policies by the government of a prime minister Shinzo Abe, which have vitalized so much the Japanese stock markets. We also follow Kawashima and Takeda (2012) to examine whether or not the accident affects more sharply companies owning nuclear power plants, companies with a major commitment of nuclear power generation, and companies owning the same type of nuclear power reactors as the one operated at the Fukushima Daiichi station during a more extended period after the accident. We use weekly data of stock returns for 10 electric power companies before and after the Fukushima accident for the sample period from April 3, 2009 to November 29, 2013. The number of observations is 244; there are 101 observations before March 11, 2011 and 141 observations from March 11, 2011 to November 29, 2013. This sample period is, relatively speaking, rather large compared to previous studies referred above of the Fukushima accident in the periods of the first couple of days and subsequent several months after the accident.

The paper is organized as follows. We explain data in Section 2. We present models and explain estimation and testing results in Section 3. We present concluding comments in Section 4.

2 Data

We use weekly data from April 3, 2009 to November 29, 2013. The number of observations is 244; there are 101 observations before March 11, 2011 and 141 observations from March 11, 2011 to November 29, 2013. We use weekly data to investigate the effect of the accident over a longer horizon. Daily stock prices in Japan are subject to daily trading limit under which daily stock prices cannot reach beyond daily trading limit. For example, when a stock price is not less than 700 yen and lower than 1000 yen, daily trading limit for the stock price is 150 yen. It is called *limit down* when a daily stock price reaches a lower bound of daily trading limit and called *limit up* when a daily stock price reaches an upper bound of daily trading limit. TEPCO's stock price recorded *limit down* right after the Fukushima accident so TEPCO's daily stock price and return have a problem of not reflecting underlying demand and supply. Thus, instead we use weekly data to capture characteristics of stock returns of electric power companies. There are 10 electric power companies in Japan which are local monopolies to supply electricity; they are named after local areas where they are supplying electricity, i.e., Tokyo (TEPCO), Chubu, Kansai, Chugoku, Hokuriku, Tohoku, Shikoku, Kyushu, Hokkaido, and Okinawa.

We present stock prices of TEPCO, Chubu, Kansai, Tohoku, Okinawa, and Topix Index at Figures 1-6 and all of six stock prices are given at Figure 7 to compare six stock prices in one figure. Six companies are chosen to show characteristics of representative electric power companies in Japan. TEPCO was most struck by the accident and its damage is enormous. On the other hand, the damage is serious for other electric power companies but not that severe compared to TEPCO. The damage by the accident for each company appears to depend on circumstances each company faces in its production and sales activities. Chubu is the third largest company and its dependence on nuclear power generation is small[1]. Kansai is the second largest company next to TEPCO and highly depends on nuclear power generation. Tohoku is a victim of the East Japan great earthquake and tsunami, occured on March 11, 2011, together with TEPCO and is thus expected to be hit hard by the accident. Okinawa is the smallest company, does not own nuclear power plants, and thus is expected not to be struck a large amount by the accident.

TEPCO has suffered most from the accident and its stock price became, at one time, almost as low as 5% of the highest price in the sample before the Fukushima accident. Thus the Fukushima accident is a disaster for TEPCO with respect to its stock price. Other companies also suffered from the accident but the damage is a lot less for other companies compared to TEPCO. Kansai and Tohoku are hit hard by the accident while Chubu and Okinawa are, relatively speaking, not that severely damaged among the four other companies. Topix Index price suffered right after the accident but its sluggish performance is not serious compared to that of electric power companies. Also we can see Topix Index enjoyed an upward trend after Mr. Shinzo Abe became a prime minister and started so-called *Abenomics* economic policies.

In addition to the figures of six stock prices, we show summary statistics of six stock returns for three periods at Table 1-6; Period 1 from the beginning of the sample till just before the accident (from April 3, 2009 to March 11, 2011[2]), Period 2 from the accident till just before *Abenomics* economic policies (from March 18, 2011 to January 4, 2013), and Period 3 from start of *Abenomics* economic policies to the end of the sample (from

[1]We follow Kawashima and Takeda (2012) to classify an electric power company whose dependence on nuclear power generation is more than 20% as large dependence and a company whose dependence on nuclear power generation is not more than 20% as small dependence and call the former as a company with a major commitment to nuclear energy and the latter as a company with a minor commitment to nuclear energy.

[2]Although the East Japan great earthquake and tsunami occured on March 11, 2011, it had almost no effect on stock markets on that day.

January 11, 2013 to November 29, 2013). Period 1 is a normal period with no effect of the Fukushima accident. Period 2 is a period after the accident with a large amount damage on electric power companies. Period 3 is a period when Japanese stock market experienced an upward trend by *Abenomics* economic policies. As seen in Table 1-5, all the electric power companies performed poorly in Period 2 compared to Period 1. TEPCO of course did worst and Kansai and Tohoku also did quite poorly. In Period 3, all the electric power companies and Topix Index turned their means positive although Kansai had negative median which is smaller than median in Period 2.

3 Estimation Results

In this section, we present estimation results of the models we use to examine the effect of the Fukushima nuclear accident on stock returns for electric power companies in Japan. Since our data of stock returns for electric power companies are panel data, we apply a standard panel data analysis to the models we analyze. Each electric power company has intrisically different characteristics which seem to be difficult to treat as a random sample, so we consider it appropriate to use the standard fixed-effects models instead of the random-effects models. In estimation, we examine the effect of the Fukushima nuclear accident and *Abenomics* economic policies on stock returns of electric power companies. Kawashima and Takeda (2012) examine stocks of nine electric power companies (with the exception of TEPCO) and a company called J-power to investigate whether the victim (Tohoku), which was hit by the East Japan great earthquake and tsunami, suffered more compared to non-victim companies, whether companies that own nuclear power plants are affected more than companies that do not own nuclear power plants, whether companies with a major committement to nuclear energy suffer more than companies with a minor commitment to nuclear energy, and whether companies that use the same type of nuclear power reactors as the one operated at the Fukushima Daiichi station, where the Fukushima nuclear accident occurred, were more affected than companies that do no use such reactors. Kawashima and Takeda analyzed the data until September, 2011, which cover a short period of time after the accident. On the other hand, we intend to study a longer period of time, until November 2013, to investigate the effect of the Fukushima nuclear accident.

First we estimate the following model for 10 electric power companies

$$
\begin{aligned}
R_{it} &= \sum_{j=1}^{10} D_j \alpha_j + \sum_{j=1}^{10} \beta_j D_j R_{Mt} + \sum_{j=1}^{10} \gamma_j D_j R_{Mt} \times D_{Ft} \\
&\quad + \sum_{j=1}^{10} \delta_j D_j R_{Mt} \times D_{At} + \zeta_1 D_{Ft} + \zeta_2 D_{At} \\
&\quad + \eta_1 dum_{1t} + \eta_2 dum_{2t} + \eta_3 dum_{3t} + \eta_4 dum_{4t} + \varepsilon_{it} \qquad (1)
\end{aligned}
$$

where R_{it} denotes a return of the i-th company at time t, R_{Mt} denotes a return of TOPIX Index at time t, and ε_{it} denotes an error term of the model. In equation (1), six different dummy variables are defined as follows;

- D_j denotes a dummy variable which is equal to 1 if j = i and 0 otherwise ($j = 1, \cdots, 10$).
- D_{Ft} denotes a dummy variable which is equal to 1 if time is after the Fukushima accident, i.e., since March 18, 2011, and 0 otherwise.
- D_{At} denotes a dummy variable which is equal to 1 after *Abenomics* started, i.e., since January 11, 2013, and 0 otherwise.
- dum_{1t} denotes a TEPCO dummy variable which is equal to 1 if the i-th company is TEPCO and time t of R_{it} is after the Fukushima accident and 0 otherwise.
- dum_{2t} denotes a victim dummy variable which is equal to 1 if the i-th company is a victim of the earthquake, i.e., TEPCO and Tohoku, and time t of R_{it} is after the Fukushima accident and 0 otherwise.
- dum_{3t} denotes an NPP (nuclear power plant) dummy variable which is equal to 1 if the i-th company owns nuclear power plants and time is after the Fukushima accident and 0 otherwise.
- dum_{4t} denotes an LN (large nuclear) dummy variable which is equal to 1 if the i-th company is a company with a major commitment to nuclear energy and time is after the Fukushima accident and 0 otherwise.

In the above model, $\alpha_j, \beta_j, \gamma_j, \delta_j, \zeta_1, \zeta_2, \eta_1, \eta_2, \eta_3$, and η_4 denote parameters to be estimated in the model. In particular, $\alpha_j, \beta_j, \gamma_j$, and δ_j denote the individual effect of the j-th company in the intercept and coefficient associated with R_{Mt}, $R_{Mt} \times dum_{Ft}$, and $R_{Mt} \times dum_{At}$ respectively. In these individual effect parameters, the numerical order of 10 companies is in turn as follows; TEPCO, Chubu, Kansai, Chugoku, Hokuriku, Tohoku, Shikoku, Kyushu, Hokkaido, and Okinawa.

TOPIX Index return R_{Mt} is employed as the market return in the above model. The coefficient of the relationship of a firm's return and the market return in the capital asset pricing model (CAPM) of Sharpe (1964) and Lintner (1965) is well-known as β, which is regarded as systematic risk. In the model (1), β's, γ's, and δ's are, respectively, coefficients of the relationship of a firm's return and market return in the whole sample, after the Fukushima accident, and after *Abenomics* economic policies. Therefore, they also stand for a kind of systematic risk in the whole sample, after the Fukushima accident, and after *Abenomics* economic policies.

The estimation result for the model (1) is given at Table 7. We have obtained a least squares estimator (LSE) and a generalized least squares estimator (GLSE) for the model (1). However, both t-statistics of the LSE obtained assuming zero serial correlation and either zero or non-zero contemporaneous correlations between different companies and t-statistics of the GLSE obtained assuming zero serial correlation and non-zero contemporaneous correlations between different companies lead to unreasonable results. For example, they make the TEPCO dummy variable dum_{1t} insignificant, which is quite unreasonable given the enormous damage of the Fukushima accident to TEPCO shown in its stock price. Thus we do not present these results. Instead, we show t-values obtained using cluster-robust variances[3] that take into account non-zero correlations for different residuals of the same company, which produce reasonable results where, e.g., the TEPCO dummy variable dum_{1t} becomes significant. We refer to Cameron et al. (2011), Petersen (2009), and Thompson (2011) among others as references of cluster-robust variances.

The fixed-effects intercept parameters of α's are all negative and 1 % significant except

[3] In our estimation results, double-cluster robust variances with respect to both company and time produce some negative variances so that we do not present t-values using double-cluster robust variances in this paper.

Chubu and Chugoku. The fixed-effects coefficient parameters of β's, i.e., the effects of the TOPIX index, are positive except Chubu and all highly significant. The fixed-effects coefficient parameters of γ's, i.e., the effects of the TOPIX index after the Fukushima accident, are all positive and highly significant. Typically, they have much larger values compared to β's. In particular, the parameter γ_1 for TEPCO is the largest and the second largest is the parameter γ_6 for Tohoku, both of which are victims of the East Japan great earthquake and tsunami. γ's increased upto more than 10 times as much as corresponding β's, e.g., in the case of TEPCO, Kansai, Kyushu, Hokkaido, and Okinawa, indicating systematic risk increased a large amount in these electric power companies after the accident. Therefore, systematic risk increased very much after the Fukushima accident. The fixed-effects coefficient parameters of δ's are negative for TEPCO, Chubu, and Tohoku, and positive for the rest of the companies and all highly significant except Chubu. On the other hand, δ's are all smaller in absolute values than γ's so that systematic risk was smaller in the period after *Abenomics* than in the period after the accident. Strucural change parameter ζ_1 and ζ_2 of the Fukushima nuclear accident and *Abenomics* are both insignificant in the model (1). The TEPCO dummy of η_1 is negative and highly significant while dummy variables of victim, NPP, and LN are all insignificant in the model (1). The NPP dummy variable is insignificant at 10% nominal level and hence companies that use nuclear energy did not perform poorly in stock prices compared to companies that do not use nuclear energy.

Then we follow Kawashima and Takeda (2012) to estimate the following model for nine electric power companies excluding TEPCO to estimate the effect of the Fukushima accident on the victim (Tohoku) of the East Japan great earthquake and tsunami

$$\begin{aligned} R_{it} &= \sum_{j=2}^{10} D_j\alpha_j + \sum_{j=2}^{10} \beta_j D_j R_{Mt} + \sum_{j=2}^{10} \gamma_j D_j R_{Mt} \times D_{Ft} \\ &\quad + \sum_{j=2}^{10} \delta_j D_j R_{Mt} \times D_{At} + \zeta_1 D_{Ft} + \zeta_2 D_{At} \\ &\quad + \eta_2 dum_{2t} + \eta_3 dum_{3t} + \varepsilon_{it} \qquad (2) \end{aligned}$$

where all the fixed-effects parameters of α's, β's, γ's, and δ's do not contain those for TEPCO, the strucural change parameter ζ_1 and ζ_2 of the Fukushima nuclear accident and *Abenomics* remain in the model (2) as in the model (1), the victim dummy variable of dum_{2t} and NPP dummy variable dum_{3t} are present in the model (2). The estimation results of the model (2) are given at Table 8. We again provide t-values obtained using cluster-robust variances that take into account non-zero correlations for the residuals of the same company.

The fixed-effects intercept and coefficient parameter estimates in the model (2) are not so different from those in the model (1). In particular, the LSEs of the fixed-effects coefficient parameters of β's, γ's, and δ's in the model (2) are quite similar to those in the model (1). Therefore, systematic risk increased a lot after the Fukushima accident but not that much after *Abenomics* period. However, their t-values are not so close to those in the model (1) and yet the significance based on the t-values is not different between the model (1) and (2) with only one exception for the parameter δ_2. In the model (2), the structural change parameter of ζ_1 is positive and 5% significant, while the *Abenomics* structural change parameter ζ_2 continues to be insignificant. The victim dummy variable η_2 is again insignificant while the NPP dummy variable η_3 is highly significant in the model (2) with nine companies. Therefore, when we exclude the data of TEPCO that were damaged enormously by the Fukushima accident, companies with nuclear power plants suffered more in stock prices compared to Okinawa which is the only company without nuclear power plants. Therefore, a conclusion based on the estimation results has changed when we replace one data with another.

We have results estimating a model similar to the model (2) with eight companies without TEPCO and Tohoku. However, estimation results for the model with eight companies do not change much compared to those for the model (2) with nine companies except for the victim dummy variable which does not exist in the model with eight companies. Therefore, we omit showing estimation results for the model with eight companies.

Then we estimate a model with seven companies without TEPCO, Tohoku, and Okinawa to investigate whether or not companies with a major commitment of nuclear energy suffered more than companies with a small commitment to nuclear energy, and companies that use old nuclear power plants built in 1970s similar to those of the Fukushima Daiichi station had more unfavorable effects than companies that use non-old nuclear power plants, and companies that use the Mark 1 nuclear power reactor as in the Fukushima Daiichi station performed more poorly than companies that use the non-Mark 1 nuclear power reactor. In other words, we estimate the following model given by

$$\begin{aligned} R_{it} &= \sum_{j=2}^{10} D_j\alpha_j + \sum_{j=2}^{10} \beta_j D_j R_{Mt} + \sum_{j=2}^{10} \gamma_j D_j R_{Mt} \times D_{Ft} \\ &+ \sum_{j=2}^{10} \delta_j D_j R_{Mt} \times D_{At} + \zeta_1 D_{Ft} + \zeta_2 D_{At} \\ &+ \eta_4 dum_{4t} + \eta_5 dum_{5t} + \eta_6 dum_{6t} + \varepsilon_{it}. \end{aligned} \tag{3}$$

- dum_{4t} is an Old dummy variable which is equal to 1 if the i-th company uses old nuclear power plants built in 1970s as in the Fukushima Daiichi station and time is after the Fukushima accident and 0 otherwise.
- dum_{5t} is a Mark 1 dummy variable which is equal to 1 if the i-th company uses the Mark 1 nuclear power reactor as in the Fukushima Daiichi station and time is after the Fukushima accident and 0 otherwise.

The results are given at Table 9. Although the LSEs of the fixed-effects intercept parameters of α's are somewhat different from those in the model (1) and (2), the LSEs of the fixed-effects coefficient parameters of β's, γ's, and δ's are quite similar to those in the model (1) and (2). Hence, systematic risk increased a large amount after the accident while not that much after the *Abenomics* economic policies. However, the corresponding t-values in the model (3) differ considerably from those in the model (1) and (2). Yet the significance based on those t-values again do not change between the model (1)-(3) except for the parameter δ_2 for Chubu. The structural change parameter of the Fukushima accident continues to be highly significant and the structural change parameter of *Abenomics* is again insignificant. Stock returns for companies with a major commitment of nuclear energy performed better than those for companies with a small commitment of nuclear energy, which is different from previous studies and counter-intuitive. The Old dummy variable η_4 is insignificant so that companies that use old nuclear power plants did not perform poorly compared to those that use non-old nuclear power plants, which is similar to the outcome of Kawashima and Takeda (2012) analyzed a short period of data of about six months after the Fukushima accident. The Mark 1 dummy variable η_6 is positive and highly significant. Therefore, companies that use the Mark 1 nuclear power reactor did better in stock prices than those that use the non-Mark 1 nuclear reactor, which is different from Kawashima and Takeda (2012) and somewhat counter-intuitive. Chugoku is the only electric power company that uses the Mark 1 nuclear reactor among seven companies. Thus the better performance of companies that use the Mark 1 nuclear power reactor simply means the better performance of Chugoku compared to the rest of the companies and may not directly imply the better performance of the use of the Mark 1 reactor.

4 Concluding comments

The Fukushima nuclear accident was a disaster that enormously affected not only electric power companies but also the whole society in Japan. In this paper we have estimated the effect of the accident on stock prices of electric power companies in Japan. We have used data of a relatively longer period to estimate the effect compared to previous studies. As the estimation method, we have applied a panel data analysis as stock return data of electric power companies are a panel data. Systematic risk, estimated as the coefficient associated with the relationship between each company's return and market return, increased very much after the Fukushima accident, indicating systematic risk increased a lot compared to before the Fukushima accident. On the other hand, systematic risk did not increase much during the *Abenomics* period. Estimation results differ as we change data. For example, when we have data of 10 electric power companies including TEPCO, the strucural change parameter of the Fukushima accident was not significant while it did become significant when we exclude TEPCO data. The TEPCO dummy variable was negative and highly significant. Given the enormous adverse effect on the stock price of TEPCO, this seems to be a quite reasonable result. However, significance of TEPCO dummy variable was possible only when we use t-values based on cluster-robust variances taking into correlations of different residuals of the same company. Therefore, it is quite important to use appropriate variances when we evaluate the estimation results in our study. On the other hand, the victim dummy variable of TEPCO and Tohoku was not significant so that the victim of the East Japan great earthquake and tsunami did not have any effects on its stock prices. The elecric power companies that use nuclear energy did not underperform compared to those that do not use nuclear energy in a model with 10 companies including TEPCO. However, the results change when we exclude data of TEPCO. When we use data of nine companies without TEPCO and eight companies without TEPCO and Tohoku, companies that use nuclear energy underperformed compared to those that do not use nuclear energy. In other words, the dummy variable of companies that use nuclear energy was not significant with data of 10 companies including TEPCO that was enormously damaged by the accident but became significant without TEPCO data. The dummy variable of use of nuclear energy was not significant in data with tremendously damaged TEPCO while became significant without TEPCO data.

In seven companies without TEPCO, Tohoku, and Okinawa, stock returns of the companies with a major commitment of nuclear energy performed better than those of the companies with a small commitment of nuclear energy, which is different from previous studies and counter-intuitive. Use of old nuclear power plants did not have any effects on stock returns, which is similar to the outcome of Kawashima and Takeda (2012). Use of the Mark 1 nuclear power reactor had favorable effect on stock prices, which is different from Kawashima and Takeda (2012) and somewhat counter-intuitive. However, Chugoku is the only electric power company that uses the Mark 1 nuclear reactor among seven companies and the better performance of use of the Mark 1 nuclear power reactor may come from other factors of Chugoku and may not be attributed to use of the Mark 1 reactor.

Our results are based on data of a longer period until November 2013 and different from previous studies that cover relatively short periods. The Fukushima nuclear accident caused enormous damages and its impact is tremendous not only in Japan but also in the rest of the world. Thus it is quite important to evaluate the outcome of the accident. We hope our results help shed a new light on this important problem.

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Table 1: Summary statistics for TEPCO

	stock returns		
	period 1	period 2	period 3
mean	-0.145	-1.207	2.567
median	-0.187	-1.843	0.578
min	-12.091	-55.681	-21.240
max	5.901	58.947	40.045
s.d.	1.442	14.630	11.592
skewness	-4.428	0.225	1.119
kurtosis	55.100	8.453	5.402

Table 2: Summary statistics for Chubu

	stock returns		
	period 1	period 2	period 3
mean	-0.015	-0.392	0.356
median	0.000	-0.435	0.088
min	-8.715	-18.954	-7.657
max	5.266	16.188	18.261
s.d.	1.477	6.085	4.462
skewness	-1.947	-0.440	1.331
kurtosis	22.317	4.109	7.028

Table 3: Summary statistics for Kansai

	stock returns		
	period 1	period 2	period 3
mean	-0.002	-0.586	0.633
median	-0.099	-0.296	-0.914
min	-5.594	-18.807	-9.877
max	4.785	22.251	33.447
s.d.	1.302	6.908	7.494
skewness	-0.657	0.347	2.029
kurtosis	13.231	4.065	9.106

Table 4: Summary statistics for Tohoku

	stock returns		
	period 1	period 2	period 3
mean	-0.133	-0.520	0.858
median	-0.025	-0.752	0.523
min	-5.109	-20.944	-11.813
max	3.967	29.395	36.864
s.d.	1.331	7.997	7.549
skewness	-0.690	0.390	2.248
kurtosis	10.294	4.688	11.938

Table 5: Summary statistics for Okinawa

	stock returns		
	period 1	period 2	period 3
mean	-0.286	-0.294	0.511
median	-0.196	-0.464	-0.413
min	-8.618	-11.200	-6.323
max	7.214	17.973	16.792
s.d.	1.622	4.066	4.457
skewness	-0.713	0.550	1.145
kurtosis	25.610	6.534	5.197

Table 6: Summary statistics for Topix Index

	stock returns		
	period 1	period 2	period 3
mean	0.134	-0.001	0.790
median	0.384	0.099	0.831
min	-6.061	-9.298	-6.941
max	9.688	5.313	7.722
s.d.	1.590	2.493	3.072
skewness	0.422	-0.405	-0.427
kurtosis	27.020	3.727	2.881

Table 7: Estimation Result for the model (1) ($R^2 = 0.173$)

coeff	LSE	t-value	coeff	LSE	t-value	coeff	LSE	t-value
α_1	-0.163	-6.908E15	β_7	0.098	150.972	δ_3	0.288	20.832
α_2	-0.129	-1.569	β_8	0.084	129.209	δ_4	0.035	2.556
α_3	-0.122	-3.979	β_9	0.016	25.208	δ_5	0.441	31.937
α_4	-0.129	-1.570	β_{10}	0.046	9.094E14	δ_6	-0.096	-6.942
α_5	-0.145	-4.727	γ_1	1.823	271764.4	δ_7	0.356	25.815
α_6	-0.158	-1.772E15	γ_2	0.856	495.973	δ_8	0.159	11.507
α_7	-0.112	-3.644	γ_3	0.924	1431.702	δ_9	0.374	27.100
α_8	-0.090	-2.952	γ_4	0.723	418.913	δ_{10}	0.111	8.081
α_9	-0.101	-3.292	γ_5	0.613	949.991	ζ_1	0.006	0.078
α_{10}	-0.292	-5.109E14	γ_6	1.154	172102.3	ζ_2	0.223	0.885
β_1	0.131	3.729E14	γ_7	0.971	1505.045	η_1	-0.039	-1.549E14
β_2	-0.015	-8.640	γ_8	1.024	1586.711	η_2	0.070	1.326
β_3	0.028	42.910	γ_9	1.057	1637.872	η_3	-0.232	-1.635
β_4	0.189	109.067	γ_{10}	0.547	81614.9	η_4	-0.149	-0.983
β_5	0.181	279.486	δ_1	-0.139	-10.083			
β_6	0.185	4.212E15	δ_2	-0.003	-0.228			

Table 8: Estimation Result for the model (2) ($R^2 = 0.189$)

coeff	LSE	t-value	coeff	LSE	t-value	coeff	LSE	t-value
α_2	-0.067	-1.906	β_7	0.098	131.862	δ_3	0.300	58.599
α_3	-0.146	-4.154	β_8	0.084	112.954	δ_4	0.052	10.226
α_4	-0.067	-1.908	β_9	0.017	22.598	δ_5	0.453	88.583
α_5	-0.169	-4.804	β_{10}	0.046	3.118E14	δ_6	-0.082	-14.115
α_6	-0.158	-1.125E15	γ_2	0.858	1156.401	δ_7	0.368	72.055
α_7	-0.136	-3.863	γ_3	0.923	1244.817	δ_8	0.171	33.421
α_8	-0.115	-3.262	γ_4	0.725	977.002	δ_9	0.386	75.524
α_9	-0.125	-3.557	γ_5	0.612	825.754	δ_{10}	0.125	21.420
α_{10}	-0.292	-1.177E15	γ_6	1.154	407085.4	ζ_1	0.084	2.490
β_2	-0.016	-21.832	γ_7	0.971	1308.622	ζ_2	-0.023	-0.212
β_3	0.028	37.978	γ_8	1.023	1379.667	η_2	0.028	0.455
β_4	0.188	251.858	γ_9	1.056	1424.175	η_3	-0.339	-5.545
β_5	0.181	243.515	γ_{10}	0.547	193050.57			
β_6	0.185	3.950E15	δ_2	0.014	2.722			

Table 9: Estimation Result for the model (3) ($R^2 = 0.191$)

coeff	LSE	t-value	coeff	LSE	t-value	coeff	LSE	t-value
α_2	-0.013	-2.807E13	β_7	0.097	97.385	δ_3	0.308	47.585
α_3	-0.101	-2.143	β_8	0.083	83.284	δ_4	0.047	7.837
α_4	-0.245	-5.029E14	β_9	0.017	124.422	δ_5	0.458	77.956
α_5	-0.176	-27.217	γ_2	0.859	292650.06	δ_7	0.376	58.223
α_7	-0.091	-1.926	γ_3	0.924	927.721	δ_8	0.179	27.677
α_8	-0.070	-1.478	γ_4	0.721	245645.13	δ_9	0.391	66.591
α_9	-0.132	-20.405	γ_5	0.612	4545.195	ζ_1	-0.317	-9.088
β_2	-0.017	-1.798E15	γ_7	0.972	975.223	ζ_2	-0.122	-1.107
β_3	0.027	27.368	γ_8	1.024	1028.116	η_4	0.105	9.417
β_4	0.191	4.055E14	γ_9	1.056	7839.782	η_5	-0.089	-1.078
β_5	0.182	1331.232	δ_2	0.023	3.738	η_6	0.491	5.938

Figure 1: Stock Price of TEPCO

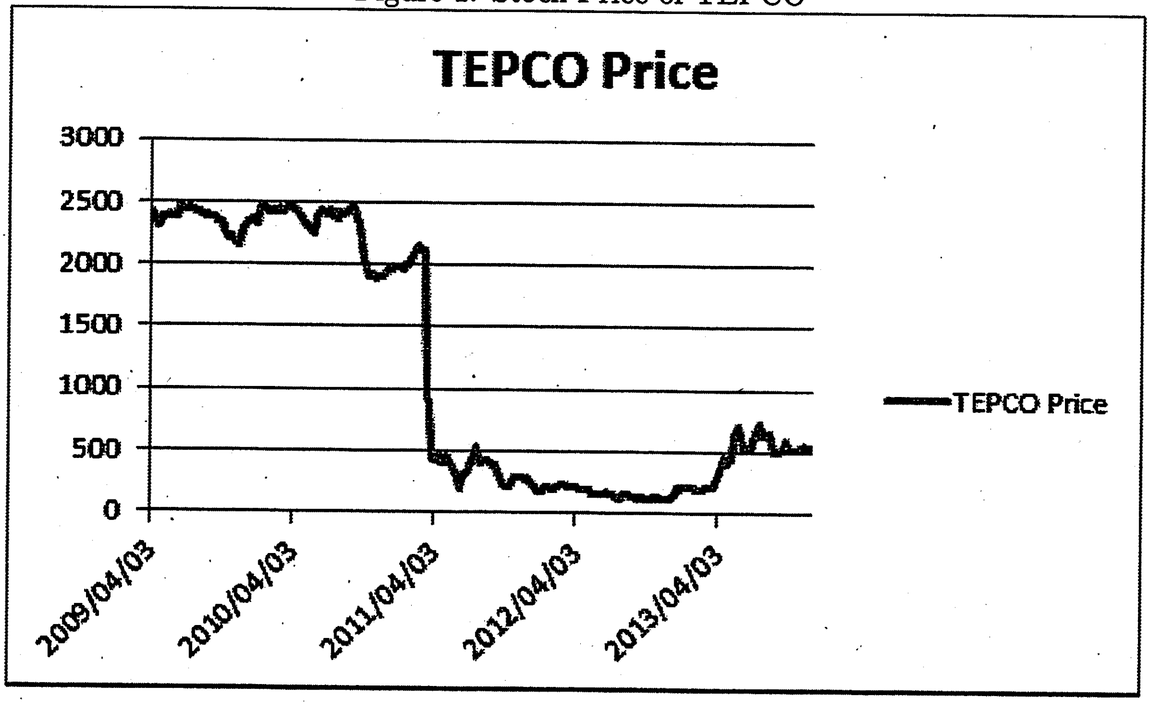

Figure 2: Stock Price of Chubu

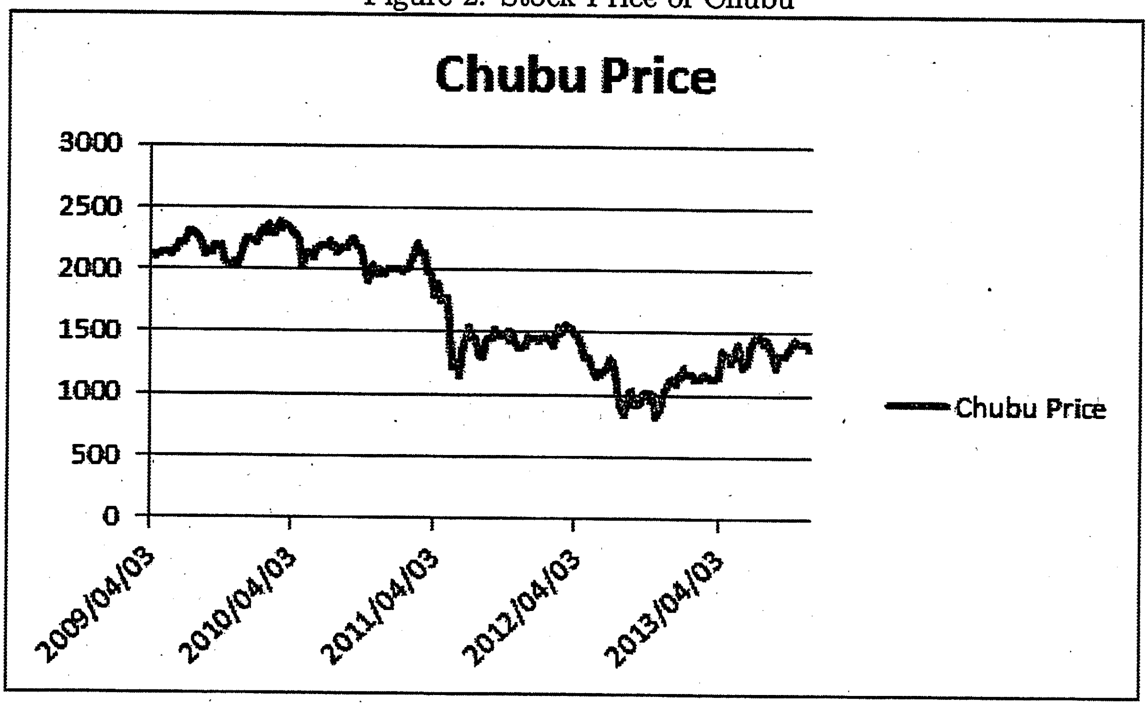

Figure 3: Stock Price of Kansai

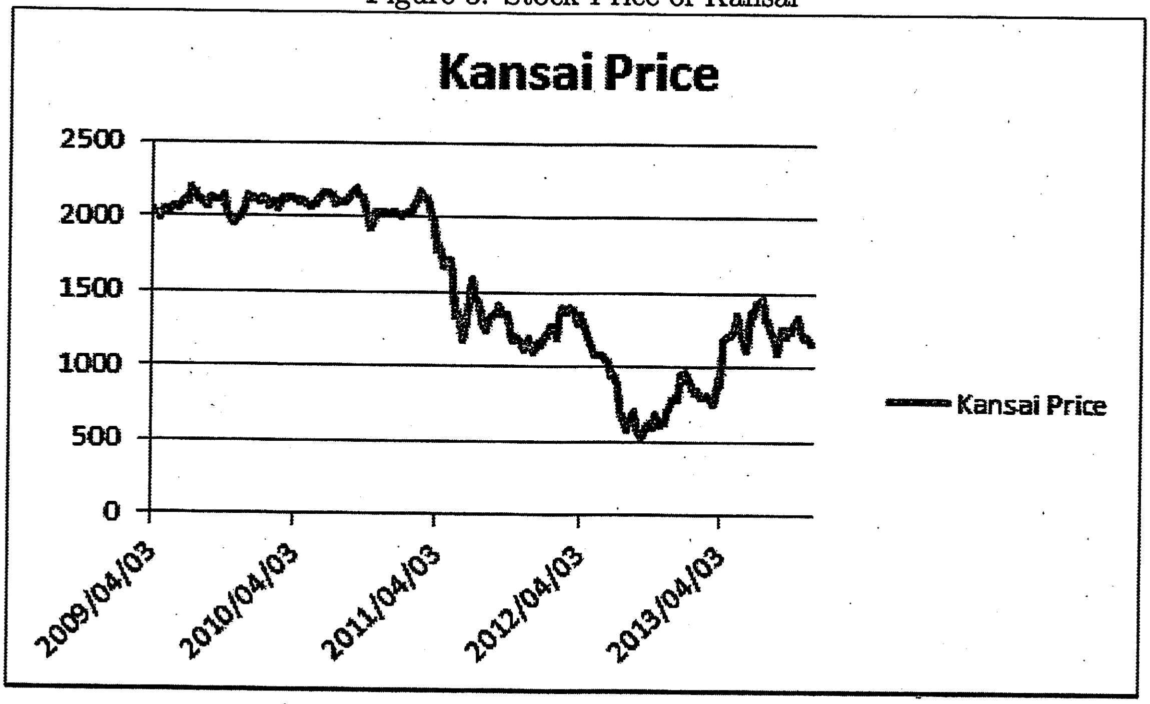

Figure 4: Stock Price of Tohoku

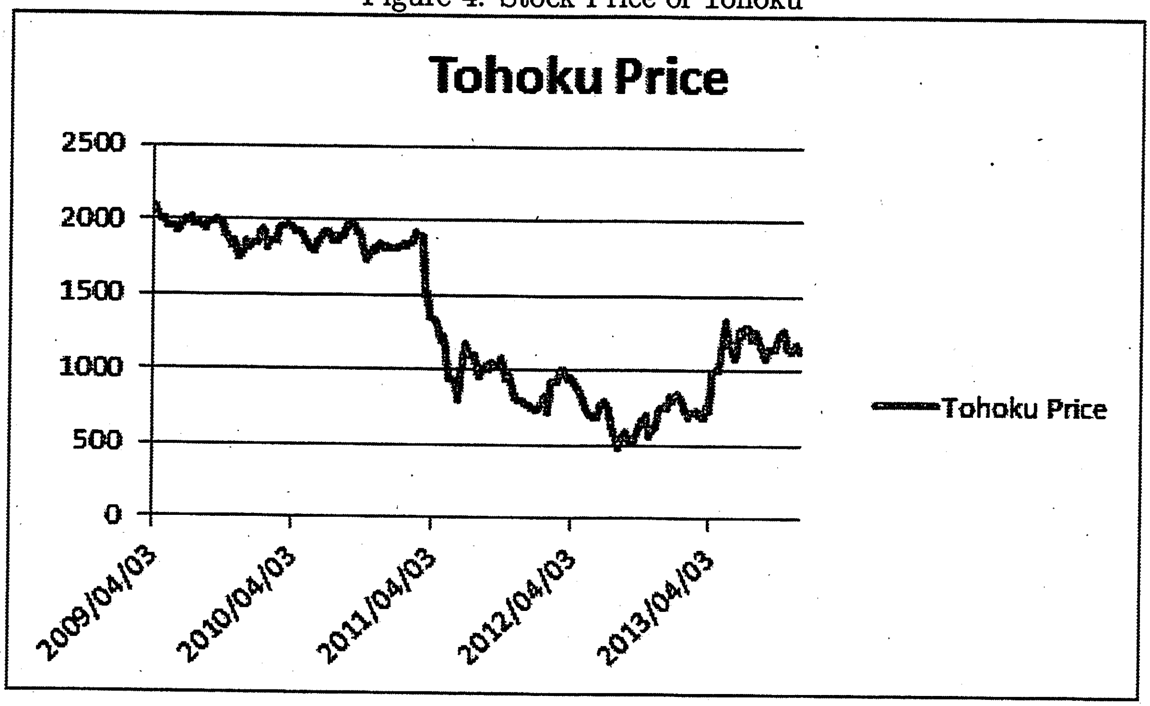

Figure 5: Stock Price of Okinawa

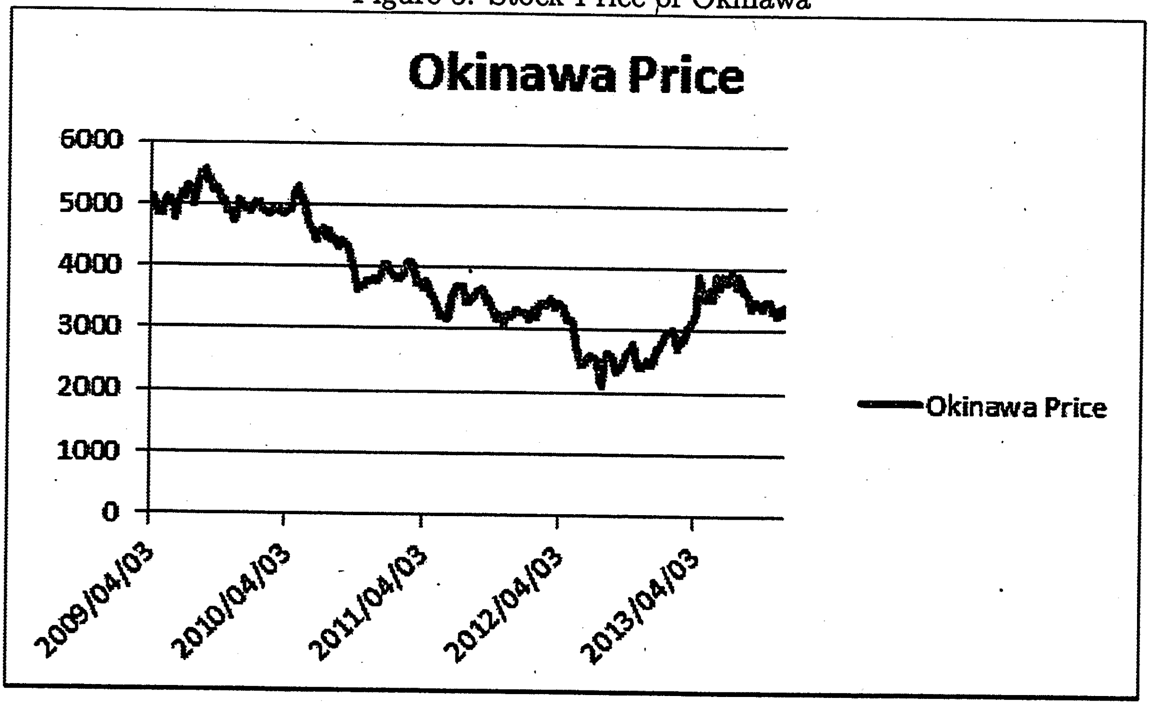

Figure 6: Stock Price of TOPIX Index

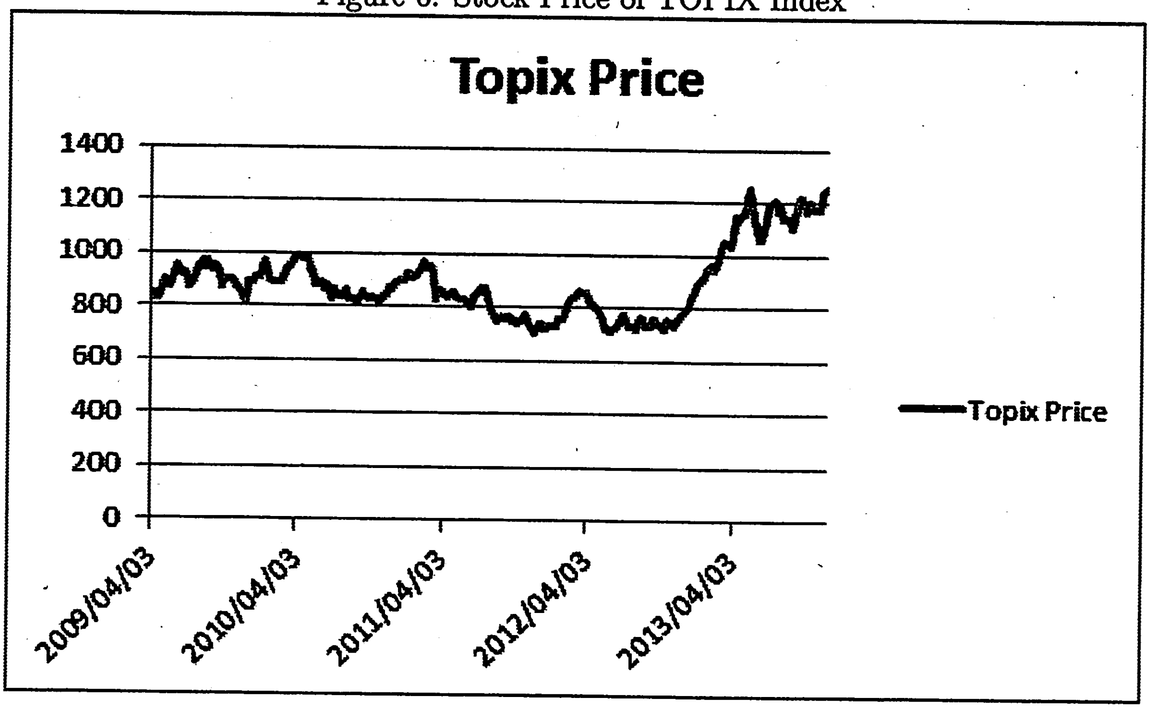

Figure 7: 6 Stock Prices