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Application of Prais-Winsten Regression in Analyzing the Relationship Between Natural Disasters and Stock Markets

Abstact This study analyzes the relationship between natural disasters, specifically storms, earthquakes, and droughts, on the stock indices of the world's five large stock markets: the United States, China, Japan, Germany, and India. By analyzing year-end closing prices from 2004 to 2022 across major indices, including the S&P 500, CSI 300, DAX, Nikkei 225, and BSE Sensex, we assess how these events influence investor behavior. Using panel regression analysis and the Prais-Winsten regression technique to address possible autocorrelation, our findings reveal that earthquakes significantly negatively affect stock markets, leading to an average decrease of 7.44% in stock indices. In contrast, there is no evidence supporting the impact of storms and droughts on these markets.

Preliminaries

Panel data

Data that is collected from the same sample group by repeatedly observing (n units) over multiple time periods within the study duration (m years).

$$(X_{it}, Y_{it}) \qquad \text{for } i = 1, 2, ..., n \text{ and } t = 1, 2, .., m$$

where X_{it} is independence variable and Y_{it} is dependence variable

Random Effects Regression

The analysis of unobservable variables not correlated with the independent variables. In this case, the unobservable are combined with the error term.

$$Y_{it} = \beta_0 + \beta_1 X_{it} + V_{it}$$

where $V_{it} = \lambda_i + \theta_t + \epsilon_{it}$

Stationary Data

Stationary data means that a time series has a constant mean, variance, and autocorrelation over time. If a time series is non-stationary, it can often be made stationary by using the natural logarithm, which can help stabilize the variance and make some non-stationary series stationary.

Autocorrelation

Autocorrelation occurs when the errors at time t are correlated with the errors at the previous time period (t – 1). This can be expressed as:

$$Cov(\epsilon_{it}, \epsilon_{it-1}) \neq 0$$

Autocorrelation may lead to biased standard errors, which in turn affects the efficiency of parameter estimates.

Durbin-Watson

This test is used to assess whether the model exhibits an autocorrelation issue

$$DW = \frac{\sum_{t=2}^{m}\sum_{i=2}^{n}(\epsilon_{it} - \epsilon_{it-1})^2}{\sum_{t=2}^{m}\sum_{i=2}^{n}\epsilon_{it}^2}$$

0 < DW < 1.5: Positive autocorrelation.
1.5 < DW < 2.5: No autocorrelation.
DW > 2.5: Negative autocorrelation.

Methodology

The panel data utilized in this study is derived from five countries, spanning the period from 2004 to 2022 then i = 1,2,3,4,5 and t = 1,2,...,19

Dependence variable

the annual closing stock market prices (Y)

- S&P 500 Index (US)
- CSI 300 Index (China)
- DAX Index (Germany)
- Nikkei 225 Index (Japan)
- BSE Sensex Index (India)

Independence variable

- The number of occurrences of storms (X1)
- The number of occurrences of earthquake (X2)
- The number of occurrences of drought (X3)
- The total number of deaths from disasters (X4)
- Total economic losses from disasters (X5)
- GDP per capita (X6)
- Consumer Price Index (X7)
- Economic Policy Uncertainty (X8)

Check the data

- Panel unit root test

The stationarity of the data is tested using the Levin, Lin, and Chu (LLC) test with Stata

- Multicollinearity

The independent variables have perfect linear relationship with any of the other independent variables.

Pearson Correlation:

$$r_{X_a X_b} = \frac{\sum_{i=1}^{n}\sum_{t=1}^{m}(X_{a,it} - \bar{X}_a)(X_{b,it} - \bar{X}_b)}{\sqrt{\sum_{i=1}^{n}\sum_{t=1}^{m}(X_{a,it} - \bar{X}_a)^2 \sum_{i=1}^{n}\sum_{t=1}^{m}(X_{b,it} - \bar{X}_b)^2}}$$

Methodology

Prais-Winsten Regression

Step 1: Run regression model to estimate parameters and calculate errors ρ. Then, use the auxiliary regression to obtain the initial estimate of ρ.

$$\epsilon_{it} = \rho\epsilon_{it-1} + \eta_{it}$$

where $|\rho| < 1$, η_{it} are independent disturbances with zero mean and variance

Step 2: Using the estimated ρ , transform the dependent (Y) and independent (X) variables:

$$Y_{it}^* = Y_{it} - \rho Y_{it-1} \quad \text{and} \quad X_{k,it}^* = X_{k,it} - \rho X_{k,it-}$$

Step 3: Run the regression using the transformed equation:

$$Y_{it}^* = \beta_0(1-\rho) + \beta_1 X_{1,it}^* + ... + \beta_8 X_{8,it}^* + \eta_{it}$$

Step 4: Use the new errors η_{it} in the auxiliary regression to update the estimate of ρ . repeat the transformation and re-estimation process until ρ stabilizes (converges).

Results

	Estimate	p-value
(Intercept)	3.6894	0.3628
X1	-0.0123	0.6182
X2	-0.0745	0.0941.
X3	0.0421	0.7278
X4	-0.0621	0.1017
X5	0.0005	0.9630
X6	0.5186	0.001**
X7	-0.7624	0.4922
X8	0.4170	0.0302*
Durbin-Watson statistic (original): 0.5841		
Durbin-Watson statistic (transformed): 1.998		

The improvement of the regression model using the Prais-Winsten method results in a Durbin-Watson (DW) statistic of 1.998, indicating no autocorrelation in the residuals. Based on the coefficient estimates, it can be concluded that the occurrence of earthquakes (X2) has a negative relationship with the closing price of the stock index. Specifically, an increase of one earthquake event will lead to a 7.45% decrease in the stock index, with a significance level of 10%. For financial variables such as GDP per capita (X6) and the Economic Policy Uncertainty Index (X8), both exhibit a positive relationship with the stock index. The significance levels for these variables are 1% and 5%, respectively. An increase in GDP by one unit will lead to a 51.86% increase in the stock index, while an increase in the Economic Policy Uncertainty Index by one unit will result in a 41.70% increase in the stock index.

Conclusion

An increase of one earthquake event per year (or a higher frequency of earthquake occurrences) leads to a 7.45% decrease in the stock market index. On the other hand, GDP per capita—which reflects the economic growth in terms of average income per individual—results in a rise in the stock market index. As the economy expands and people's incomes grow, consumption and investment in the business sector increase, leading to higher profits for companies, which is reflected in the rising stock prices. The Economic Policy Uncertainty Index (EPU) measures the level of uncertainty regarding economic policies, such as changes in fiscal or monetary policies, or events that create concerns in financial markets. When EPU increases, indicating higher levels of uncertainty in policy or economic direction, investors may become concerned about future economic risks, leading to adjustments in stock prices.