The Impact of Extreme Weather Events on the Economic Performance

Nuoyi Su[1, †], Haotian Wen [2, *, †]

[1]Weihai IVY International School, Weihai, China

[2] Beijing-Dublin International College, Beijing University of Technology, Beijing, China

[†]These authors contributed equally

182151656@st.usst.edu.cn

*Corresponding author: haotian.wen@ucdconnect.ie

Abstract. With the increasing number of populations, the environment on the earth is seriously damaged, leading to a lot of weather disaster such as extreme high temperature in summer, global warming and so on. These events have a considerable number of impacts on human, especially for economy. This paper represents a comprehensive review of research dedicated to the effects of weather events on economy. During the research, a considerable number of papers about the impact on the economy were referred. Based on the statistical data and deeply analysis, it can be found that weather have a lot of negative impact on both agriculture, industry, and energy consumption. In the future, with the development of machine learning algorithms, and cloud computing, the simulation of chaotic systems such as weather and climate will be more accurate. Climate change poses great challenges in economics, and it is the largest and broadest market failure phenomenon so far. Therefore, it is necessary and urgent to study the economics of climate change.

Keywords: Extreme weather event; Economy; Global warming.

1. Introduction

With global warming, the frequency of extreme weather in some areas has gradually increased. Global warming is a common topic all over the world. The convening of the United Nations Climate Change Conference (UNCCC) pushed the concern of human society on global warming to a new stage. With global warming, extreme weather also occurs more and more frequently. The weather phenomena that occur once every ten years or even once every hundred years often occur.

Since the beginning of summer in June 2022, Sichuan and the Yangtze River Basin have entered the state of red high temperature warning for many consecutive days. The temperature in Chengdu has been above 40 ℃ for more than ten consecutive days. Such extreme weather has had an impact on the urban economy. With the increasing demand for air conditioning and other refrigeration equipment in high temperature weather, the pressure of the power grid also increases. Since June, the load of Jinan Jiyang power grid has hit a record high four times; The power load of seven provincial power grids as well as the northwest power grid, reached a record high. On July 11, the highest power load of the whole society in Zhejiang Province exceeded 100 million kilowatts, setting a record. On July 12, the load of Hefei Power Grid reached 10.133 million kilowatts, a record high, an increase of 15.9% over the maximum load of last summer; The dispatching power load of Jiangsu power grid has reached 126 million kilowatts, which means that the dispatching power load of Jiangsu power grid has reached more than 100 million kilowatts for 24 consecutive days. Heat radiation sickness has gradually entered the public's field of vision. Under the influence of heat wave, the result caused by power failure may be fatal, because many buildings cannot turn on air conditioning [1]. More than 70000 deaths in Europe in 2003 were related to heat waves. With the increase of global aging, these consequences will become more and more serious [2]. In addition, due to the unpredictability of extreme weather, the insurance industry has also been affected.

With the deepening of climate research, there are more and more research materials about the impact of various industries on extreme weather, including agriculture, industry, and energy. These articles use different methods and models to study these impacts.

This article will give a review of these research materials and articles. This paper will first describe the methodologies and models related to these papers. After that, this paper will focus on the impact of extreme weather on agriculture, industry, and energy. Finally, this paper will discuss and summarize the emerging models.

2. Methodology

During the research, the authors first referred to more than 20 papers about the impact on the economy. In the next stage, it will divide the main part of the paper into three parts include: the impact of extreme weather on agriculture industry production and energy consumption. For the main parts, this paper cited at least more than 10 papers for the article, during the period from 1900 to 2020, include the areas of North America, Asia, and Europe.

3. Overview of Models

3.1 Spatial Panel Model

Everyone lives in a world of time and space. Every event occurs at a specific time and place with time and location are measured. Such data called spatial panel model, which refers to time series observations of a certain space unit. When studying practical questions, the spatial panel data itself has more degrees of freedom, richer in information and more variation. Spatial Panel Model proposed for spatial panel data analysis. Compare with general regression models and spatial regression models, it can improve the effectiveness of high parameter estimation, spatial models play an important role in the search for scientific explanations. Through Spatial Panel model, the temporal and spatial distribution characteristics of the research objects can be better combined, and the influencing factors and laws can be found.

3.2 Standardized Precipitation Evapotranspiration Index (SPEI)

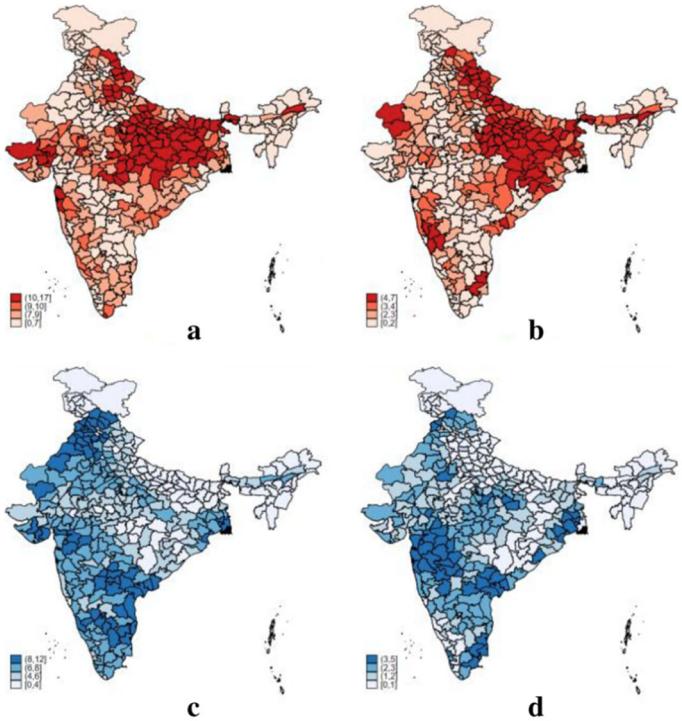

Fig. 1 The diagrams show the number of events in each district from the 20th century to the early 21st century with a SPEI of between +(-)1 and 1.5. these four graphs show rates of accident happens in different regions by using SPEI [3].

This index, as shown in Fig. 1, is an index representing the wet and dry state calculated using precipitation and air temperature data. It can be calculated on various time scales (January, March, December, etc.). It is widely used in drought research. It is further developed from the normalized rainfall index of Standardized Precipitation Evapotranspiration Index (SPI), it also combines the effect of evapotranspiration. It is more applicable in areas with significant temperature changes and is especially suitable for long-term research [3].

3.3 Time Series Regression Models

Time series refers to a sequence of numbers formed by arranging the values of the same statistical indicator in the chronological order of their occurrence. The main purpose of time series analysis is to predict the future based on existing historical data. There are four commonly used time series models: autoregressive model AR, moving average model MA (q), autoregressive moving average model ARMA, autoregressive differential moving average model ARIMA.

ARIMA model is built based on stationary time series, so the stationarity of time series is an important prerequisite for modeling. The ADF unit root test model is generally used to test the stability of the time series model. Of course, if the time series is not stable, researchers can also make the time series stable through some operations (such as logarithm and difference), and then carry out ARIMA model prediction to obtain the prediction result of a stable time series. Then, you can carry out the reverse operation of the previous operation to stabilize the series (the reverse operation of index and difference) to obtain the prediction result of the original data [4].

4. Agriculture

4.1 The Impact on the Crop Yield

Extreme weather is one of the most significant factors that have a great impact on the agriculture, such as the yield of crops or the price of the vegetables. Francisco Fontes and his team use the Standardized Precipitation Evapotranspiration Index (SPEI) to discover the influence of extremely high temperature on the water demand and find out the relationship between SPEI and the yield of crops. It shows that the drier the weather conditions are, the greater the impact will influence the yield of crops. They calculated the influence of the SPEI on yield for some crops which are the main source of the total caloric intake. If the temperature is higher than 30 degrees, the maize yield will be reduced. The higher temperature is more than 34 degrees, which is harmful for wheat. There is a negative effect on rice between 30 and 40 degrees. Beyond these temperatures, grain production will be greatly affected or even reduced by two or three times.

Leng and Hall have also found the impact of rainfall and extreme drought on agriculture production by using plant specific standardized precipitation index, create a probabilistic modeling framework to measure the risk of crop loss. If the value of SPI is lower than -0.8, then it will be regarded as drought, which will reduce the yield of plants and increase the probability of crop failure. It is also found that the annual change of soybean production has the greatest association reference to drought index. When extremely facing drought the yield of soybean and maize will be reduced for more than 70%, while the risk for rice is 68%. If the degree of drought become worse, the degree of loss will continue to increase [5].

4.2 The Impact on the Price of Vegetables

With the decreasing output of agriculture products, the prices of crops continue to rise which also lead to an increase in the price of vegetables especially for leafy greens. Vegetables are useful for all the people around the world, they can provide special nutrition for human body such as vitamins or mineral even the food for poultry feed. Due to climate change, the price of tomato has gone up by 200% and the price for potato rose for 150%.

To find out the relationships between extremely weather and the price of vegetables, Gebregewergs and Hadush use time series regression models with mainly two functions and the

dynamic causal effect with situation by using lag values in the future are estimated. They use the percentage change and two-way change to show the trend of the price for vegetables ups and downs. During the past ten years, prices of tomato in 2015 went up for more than three times.

Another person Tobias Dalhaus who uses regression analysis to measure the influence of temperature change in the period of apple flowering on the price of apple and production in one single time. To avoid error items, heteroscedasticity robust standard errors are used, which are the two-way clustered with time and areas by using piecewise linear way to find out values which shows a clear nonlinearity [6]. According to macroeconomic, the prices of agriculture products continued to rise, and the prices of vegetables will rise accordingly. And the increase in the labor cost will also rise the price of green leafy vegetables. They have a narrow growth cycle which will be relatively affected by the weather conditions. In summary, different factors that have influence on agriculture can be shown in Table 1.

Table 1. Factors that have influence on agriculture

Production of crops	Impact factor	Observed Features	Models	Results
Production of crops	The temperature of the weather	It shows that the drier the weather conditions are, the greater the impact will influence the yield of crops.	SPEI	Grain production will be greatly affected or even reduced by two or three times if the temperature is too high and dry
Risk of crop loss	Rainfall	It is found that the annual change of soybean has the highest correlation with drought index, followed by rice, wheat, and maize.	SPI	When extremely facing drought the yield of soybean and maize will be reduced for more than 70%, while the risk for rice is 68%. If the degree of drought become worse, the degree of loss will continue to increase.
Price of vegetables	Extreme weather condition	In the past five years, the price of vegetables has risen a lot, even tripled	Time Series Regression Models	Favorable weather conditions correspond to low organic price premia. A statistical relationship exists between vegetables price premia and temperatures
Production and the price of apple	Freezing weather	The influence of weather on it shows a nonlinear relationship	The multiple regression	Idiosyncratic spring frost events induce only minor drops in yields while they cause farm gate price and thus revenue reductions of up to 2.05% per hour of exposure

5. Industry

5.1 Impact on the Construction Industry

The accident rate in the construction industry remains high, more than three times that of other general industries. As a special industry, the proportion of outdoor operations in the construction industry is higher than that in the general industry. Working outdoors is more susceptible to the weather. The hot and high temperature in summer and the cold and freezing in winter will make

outdoor constructors sickly, so temperature is also the main meteorological factor to improve the working efficiency of constructors. When the outdoor temperature is close to 23 ℃, the working efficiency of construction workers is the highest. In a Polish survey, summer is the season with the highest number of casualties among workers in a year. Temperature is closely related to the hydration of concrete. The increase of temperature will reduce the water content of concrete and sand. In case of extreme high temperature, it is necessary to add reagents to maintain the concrete at normal level. After the temperature of some buildings rises in summer, the installed plates will expand, bulge, deform or misplace, which is also caused by the shrinkage of plates in the low temperature environment during the initial construction [7].

High temperature weather will also affect the industry related to building materials, resulting in insufficient production of building materials. For example, the output of cement, concrete, sand and earth will be lower than the demand. And then affect the construction efficiency of the construction site.

5.2 Impact on Industry Output

The impact of extreme weather such as high temperature on factory output is also huge, although more people pay more attention to manual labor, such as construction and agriculture. Some studies have pointed out that the average output of factories in Caribbean countries will decrease by 2% for each degree of temperature rise in summer. After production in the factory, extreme weather has a great impact on its transportation. Typhoon, as the representative of extreme weather in coastal areas, has hit coastal cities. Typhoon Haiyan in 2003 caused at least 6000 deaths, 28000 injuries and $4.4 billion in economic losses. The extreme weather not only caused the shutdown of the factory and the construction site, but also hindered the port transportation [8].

Australia is a good example of extreme weather. Heat waves, floods and typhoons all shut down the port. As ports bear important transport responsibilities, the cost of port operation interruption is high. In addition, Taiwan and Japan export many parts of modern industrial products, including semiconductors, electric vehicle batteries, etc. The port outage will greatly affect the global supply chain. American ports are also vulnerable. Researchers have defined several relevant attributes to assess the extent of damage to many ports [9].

6. Energy

6.1 The Impact on the Consumption of Energy

Extreme weather conditions will affect the use of energy, for example, in the hot summer, people will increase the frequency of using air conditioners which will increase the consumption of electricity and during the cold winter, more fuel will be burned to maintain the room temperature. Because of the extreme high temperature weather, the consumption of energy booms up sharply which increase the pressure of energy supply. The lack of electricity had caused plentiful number of irreversible effects on society. To find out the relationships of extreme weather and energy consumption, a lot of teams try to solve this issue.

Subak and his team fit monthly data linearly and find that the total use of gas, electricity and fuel had declined because of the consumption of gas and electricity increased continuously so they had used a single linear fit. And the data were then correlated and regressed with the central temperatures of each month. The correlation analysis climate that with the increasing of global temperature, the consumption of gas was the lowest while the use of electricity is the highest and the total consumption of electricity in the third quarter which means that the use of air conditioner or refrigeration will keep increasing [10].

Due to the uncertainty of extreme climate change, people are changing their structure of consumption of energy. Different country has different energy transition when facing the extreme weather condition. Jiaying Peng and her team had worked on this, firstly they thought about the

estimation deviation caused by missing variables at individual levels, time invariant variables should be removed, and they have built spatial panel model with some single influences, which contains the proportion of consumption of renewable energy due to the use of initial energy consumption (ECT) and climate risk index (CRI). The climate risk of coastal countries is higher and climate risks are negatively proportional to changing the types of energy, which means that higher the risk of extreme weather conditions, higher the rate of renewable energy will be used. The burn of fossil energy will increase the risk of climate change so in long terms, countries are more willing to encourage to transit energy consumption to protect the environment [11].

7. Discussion

An Australian study simulated a model to explain the effects of extreme weather on ports. Prem Chhetri et al. designed a Container Terminal Operation Simulation. It can simulate the working conditions of each unit in the port to observe the individual and collective behaviors of each unit in extreme weather. As a result, they simulated that the transport efficiency of Sydney Port decreased by 13% after a long period of extreme weather. Their CTOS is agent-based modeling. ABM allows independent operation and observation of behavior at the same time. Such characteristics make ABM easier to model than pure mathematical methods. CTOS simulates the container movement operation of a certain terminal in Sydney Port, rather than the whole Sydney Port. The advantage of this is that the simulation is more detailed and closer to the actual situation. However, the disadvantages are also obvious. The scope of CTOS simulation is too small to simulate the whole Sydney Port. Simulating the influence of extreme weather on the whole port is hard. In addition, there are limitations in predicting the future. The port management did not have a specific plan time point more than ten years, nor could it provide a list of specific assets soon, so CTOS could not carry out accurate simulation, and it was difficult to be effective for forecasting [12].

In the future, with the development of machine learning algorithms, and cloud computing, the simulation of such chaotic systems as weather and climate will be more accurate. The most obvious result is that the accuracy of weather forecasting will increase. The improvement of the algorithm makes the unit logic in the model more realistic and easier to simulate the precise influence of extreme weather on the production and life of the human world. With the simplification of operations, it is more likely that the model will be directly handed over to users for customization. Users can plan their own assets in detail, which can make the risk management and control of users more reasonable.

8. Conclusion

With the continuous emergence of extreme climate, the authors believe that the disasters they bring should be paid attention to. One of the reasons for global warming is human activities. Reducing carbon emissions can alleviate global warming and reduce the frequency of disastrous weather. Research data in various fields about the serious consequences of extreme weather are also significantly increasing. This paper includes some of them to describe the impact of extreme weather. For some industries, there are also articles on disaster simulation. Although they all have limitations, they can also remind managers to conduct risk management and control. The significance of this paper is to discuss the impact of extreme weather on industry, agriculture, and energy, and to help decision-makers in risk management and control.

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