The Correlation of Climate Change, and Consumer Food Prices

ECON 400 – Bellevue College

Final Research Paper

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I. Introduction

The economic impact of climate change has been a topic of recent study, in addition to heated public debate. The Congressional Research Service has stated that the two main avenues for climate change to affect the US economy are through productivity and investment effects[1]. The purpose of this research is to look at productivity, and the resulting changes that can be felt by consumers at the end of the supply chain. There are many factors that will impact the price that consumers pay, but the output of agriculture due to fluctuations in weather and growing conditions is a good indicator of how climate change will impact consumers.

According to the report by the Congressional Research Service, the reduction in GDP per capita growth is as high as 0.0586 percent per average annual temperature increase of 0.01 °C. If there was to be an increase of 0.04 °C annually, we could see a reduction of 7.22% by 2100[1]. This is a good indication of how the economy will feel the impact of climate change, but it does not indicate how consumers will feel it. A more direct impact was found in an article by Laurence Chandy for Carnegie Endowment, with data indicating that that a rise of 1 °C in a given year caused the per capita income to fall by 1.4 percent on average[2]. This is likely to be caused by decreases in agricultural productivity, eventually leading to workers and consumers feeling the effects further down the chain.

For this research, I have decided to approach the problem purely from the impact on consumer prices. The supply chain should impact consumer prices, and we have seen an increase of 321% since the standardization of prices in 1983[3]. According to the same report from the Congressional Research Service, the changes in moisture and temperature due to rainfall will have a significant effect on our fisheries and farmland. So, I will be using CO^2 levels, the monthly average change in temperature, the average sea level, the US Industrial Production Index for non-durable goods, and drought conditions to model the growth of the Consumer Price Index for all non-durable goods. Given that there have been three notable recessions in the US since the 1990s (2000, 2008, 2020), I will be accounting for it by looking at the interaction between it and the other factors.

II. Data

The data came from multiple sources and was organized by month and year from January 1993 to December 2020. Data on the Consumer Price Index, Industrial Production Index, and the binary data on US Recessions as observed by its effect on the GDP were obtained from the Federal Reserve Bank of St. Louis. CO^2 concentrations and Sea Level changes were obtained from the Climate Change Dashboard run by the International Monetary Fund, this data had to be averaged by month to match the other data sets. The data on surface level temperature changes was obtained through the Food and Agriculture Organization of the United Nations, with a focus on the continental US. The final data set came from the National Oceanic and Atmospheric Administration through their Drought Information System, it is the percentage of the continental US landmass under either a severe drought or severely wet conditions.

Each data set was clean and assembled by matching their sampling dates, by months and then year. The final data set consists of 1 response variable, 7 predictors, and 336 observations from 1993 to 2020.

III. III. Modeling Methodology

a) Variable Description

- Consumer Price Index (CPI) – Scaled variable with a standardized score of 100 in 1983 being the baseline. This is an indicator of the average change of non-durable goods such as food and beverages over time.
- CO^2 – Concentration of Carbon Dioxide in the atmosphere in a unit of parts per million.
- Temperature Change - Average monthly change in temperature for the Continental US in degrees Celsius.
- Industrial Production Infex (IPF) – The real US production of non-durable goods, all food and beverage products in addition to tobacco.
- SevereDry – Percentage of Continental US land that is experiencing a severe drought.
- SevereWet - Percentage of Continental US land that is experiencing a period of severe moisture.
- Recession - Quarterly binary factor to indicate presence of a recession as reflected in the GDP, the value for each month is a copy of the quarter they exist in.

b) Descriptive Statistics

Table 1

Statistic	N	Mean	St. Dev.	Min	Max
CPI	336	202.080	39.222	139.100	270.852
SeaLevel	336	21.018	25.031	-25.983	77.147
CO2	336	383.758	17.004	354.140	417.310
TempChange	336	0.887	0.904	-1.031	3.815
IPF	336	94.657	4.125	83.820	102.515
SevereDry	336	8.059	7.014	0.100	32.400
SevereWet	336	14.730	8.630	1.200	51.400
Recession	336	0.107	0.310	0	1

The data has a sample size of N = 336, with a mean Consumer Price Index of 202.08, and a maximum of 270.85 for the period studied. For climate effects, there was an average CO^2 concentration of 383.76 parts per million, an average temperature fluctuation per month of 0.887 °C. For drought effects, on average 8.06% of the US was in a state of severe or greater drought while 14.73% was in a state of excess moisture in the form of floods or deluges. For the production factors, about 10.7% of the data set contained months during a detected recession and the data had an average Industrial Production Index value of 94.66.

c) Modeling Method

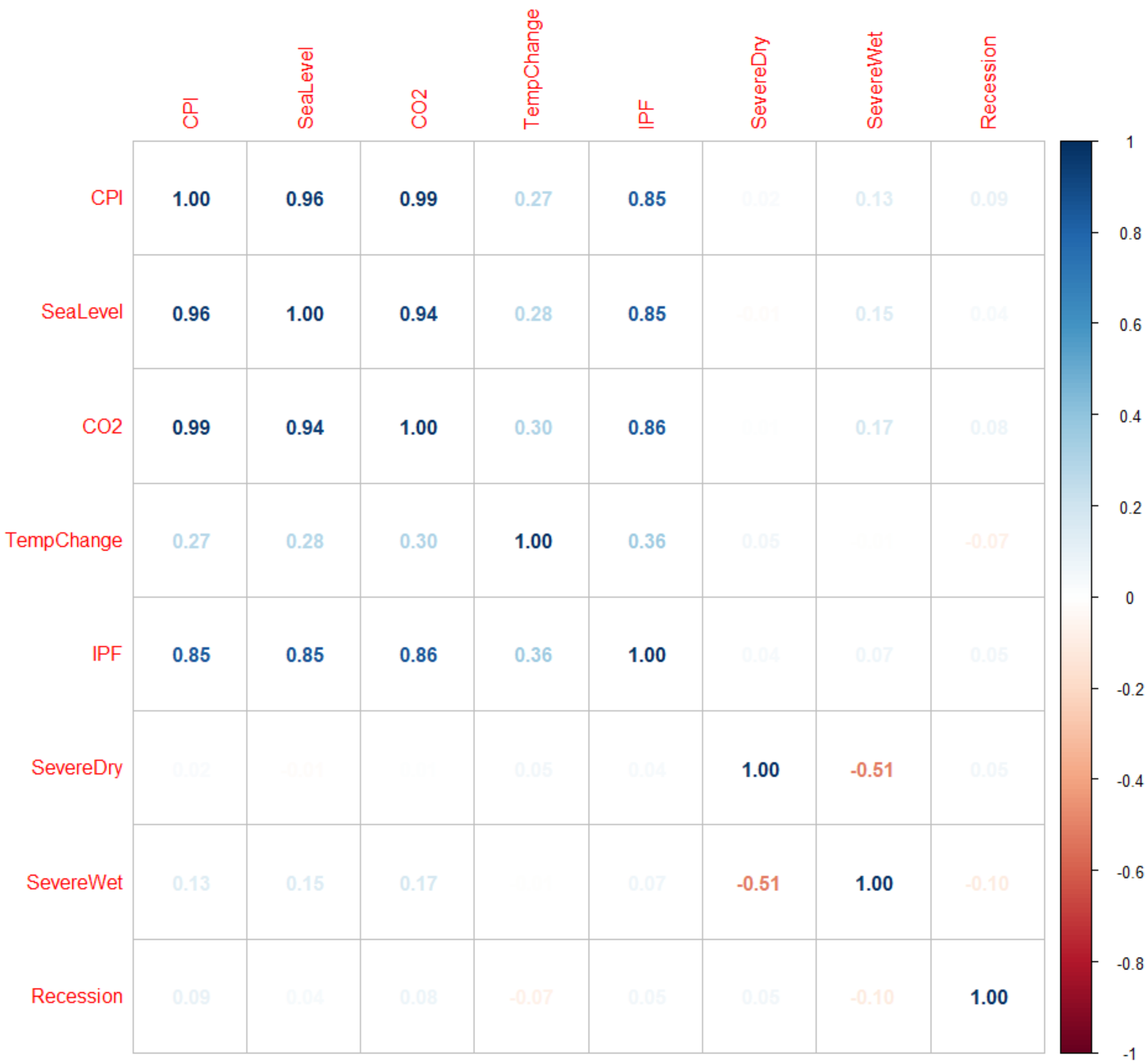
The correlation was checked for all factors, to check for multicollinearity and to see how well they correlated with the response variable. Highly correlated variables were removed so that multicollinearity would not become a problem, and then OLS was applied to the data set. Due to heteroskedasticity the White's Test was applied to see if a WLS model would be more appropriate, and it was found to be more appropriate for this data.

The first model did not include SeaLevel due to a near perfect correlation between it and CO2, so the initial WLS model had 6 factors and interactions between Recession and all other factors. Each variable that was not significant to an alpha of 0.05 was removed one by one, starting with the highest P-value, until all variables and interactions were significant.

$$\text{CPI} = c + b_1\text{CO2} + b_2\text{TempChange} + b_3\text{SevereWet} + b_4\text{Recession} + b_5\text{CO2*Recession} + b_6\text{SevereWet*Recession}$$

IV. Analysis

a) Correlation



Sea Level and CO^2 are highly correlated, due to this Sea Level will be removed as a factor. In addition, IPF is highly correlated but does not exhibit perfect correlation so it will be checked for significance before removal.

b) Models and White's Test

Table 2: OLS and WLS Model Comparison

	CPI				
	OLS	WLS 1	WLS 2	WLS 3	WLS 4
CO2	2.341***	2.339***	2.326***	2.323***	2.326***
	(0.044)	(0.044)	(0.023)	(0.023)	(0.023)
TempChange	-1.039**	-1.114***	-1.147***	-1.150***	-1.315***
	(0.428)	(0.423)	(0.414)	(0.415)	(0.403)
IPF	-0.101	-0.064			
	(0.179)	(0.171)			
SevereDry	-0.033	-0.050	-0.050		
	(0.060)	(0.059)	(0.059)		
SevereWet	-0.186***	-0.175***	-0.171***	-0.149***	-0.149***
	(0.050)	(0.050)	(0.050)	(0.042)	(0.042)
Recession	187.727**	184.146**	225.542***	178.844***	195.066***
	(78.791)	(82.478)	(71.150)	(59.382)	(58.782)
CO2:Recession	-0.680***	-0.690***	-0.595***	-0.479***	-0.529***
	(0.195)	(0.209)	(0.189)	(0.163)	(0.161)
TempChange:Recession	-2.757	-2.649	-2.000	-2.851	
	(1.939)	(1.977)	(1.873)	(1.732)	
IPF:Recession	0.760	0.833			
	(0.758)	(0.805)			
SevereDry:Recession	-0.405	-0.413	-0.383		
	(0.359)	(0.368)	(0.367)		
SevereWet:Recession	0.824**	0.844**	0.887**	0.812**	0.889**
	(0.343)	(0.354)	(0.351)	(0.347)	(0.345)
Constant	-682.784***	-685.687***	-686.566***	-686.260***	-687.285***
	(8.912)	(8.705)	(8.450)	(8.446)	(8.444)
N	336	336	336	336	336
R2	0.974	0.975	0.975	0.975	0.974
Adjusted R2	0.974	0.974	0.974	0.974	0.974
Residual Std. Error	6.380 (df = 324)	1.239 (df = 324)	1.236 (df = 326)	1.229 (df = 328)	1.222 (df = 329)
F Statistic	1,121.593*** (df = 11; 324)	1,137.211*** (df = 11; 324)	1,394.754*** (df = 9; 326)	1,792.565*** (df = 7; 328)	2,080.898*** (df = 6; 329)

The initial OLS model failed the White's Test (appendix A), and as such Model II above is using a WLS method. IPF already had problems with high correlation, so it was removed due to the lack of significance. Next, the SevereDry was omitted due to the lack of significance. This indicates that US agricultural production may not be affected by droughts, likely due to the systems put in place for the last century. Finally, the interaction between Recession and TempChange was removed due to lack of significance. This leaves the final model of:

CPI = f{CO2, TempChange, SevereWet, Recession, CO2*Recession, SevereWet*Recession}

For this final model, all variables and interactions remaining are statistically significant to an alpha of 0.05. CO^2 has a positive relationship with CPI, while the change in temperature and areas of greater moisture have a negative relationship. Recession interacts with nearly all other variables and has a massive positive relationship by itself with CPI.

V. Conclusion

I expected that CO^2 would have a positive impact on the Consumer Price Index due to how it affects our fisheries. Ocean acidification leads to worse yields, and lower quality yields. However, I did not expect that a change in temperature would have a negative relationship with the Consumer Price Index. Accounting for a recession proved to be good, as it had significant interactions with nearly all of my final factors except for the change in temperature. The impact of a recession alone is incredibly large in this model, which is contrary to the expectation that supply, and demand, would drive the price of non-durable goods down as disposable income falls.

By far the most surprising discovery was the lack of significance in droughts. While beginning this experiment, there was an expectation that a drought would increase food prices due to a lack of production and stable demand. However, it was not statistically significant and instead excess precipitation had a negative impact on the Consumer Price Index. This is likely due to the systems that the US has implemented over the last century to combat droughts, especially in areas such as the central states where water will go to agriculture first in times of drought. These same systems likely also account for excess water entering the system, and as such will increase reservoir volume to help deal with the next drought. This means that a lack of precipitation has no statistically significant effect on the prices that consumers would feel on average for the month. There may be a small, localized impact, but there is no impact for the entire continental US.

The model can account for 97.4% of the variance, but it does not pass the Shapiro-Wilk Test at an alpha of 0.05 (appendix E). However, it does pass it with an alpha of 0.01 so while it is not the best model for the situation there is still much to be learned from it. The main reflection would be the correlation between CO^2 and CPI, as this may be a reverse relationship where the changing prices due to increased demand may be driving the increasing pollution. Correlation is not causation, and there are likely to be better methods of observing the economic impact of climate change. In addition, I was not able to find the optimal functional form as my final model failed the RESET Test for specification even when various transformations were applied.

VI. Appendix

a) White's Test

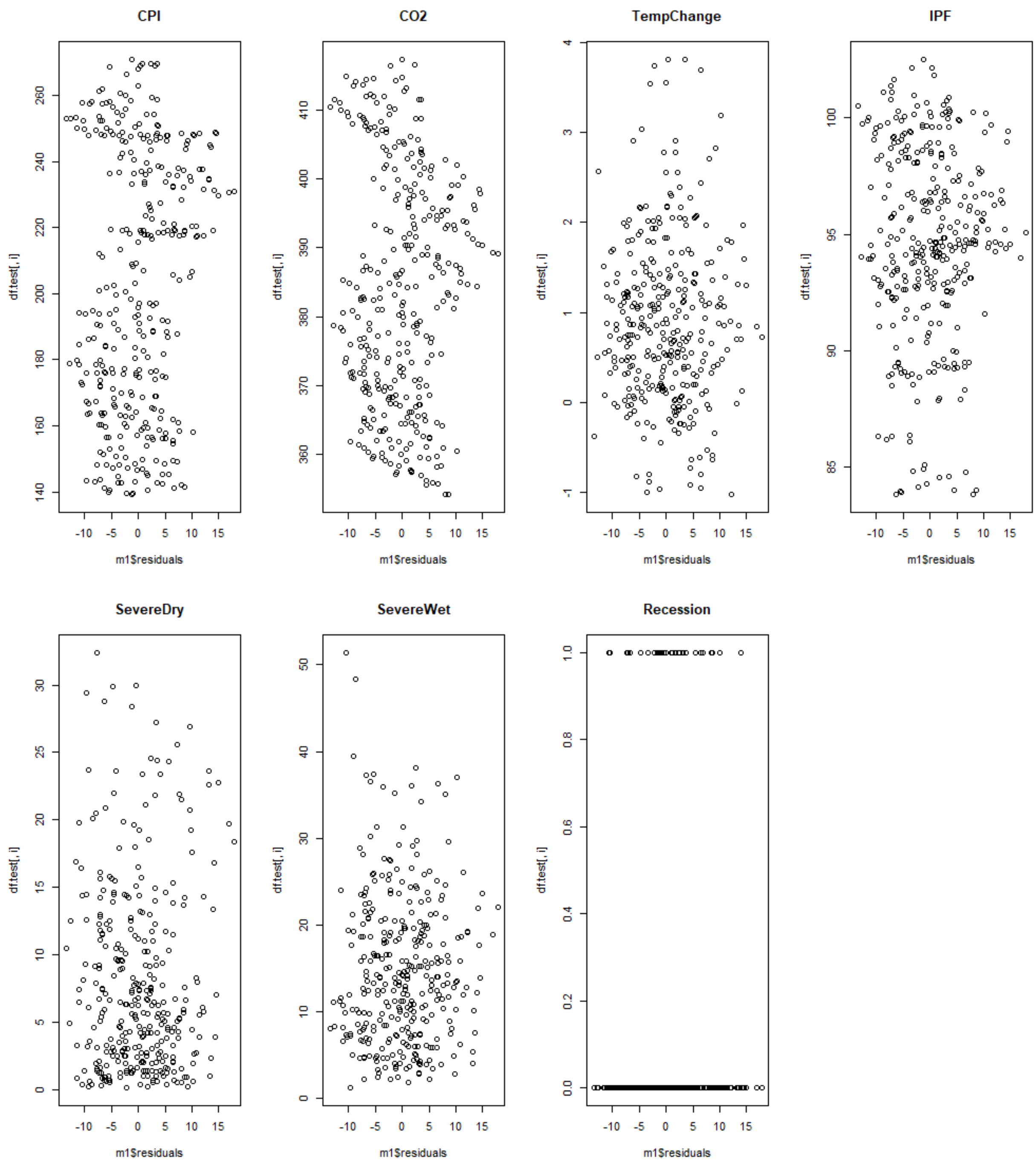
```
> bptest(m1, ~fitted(m1)+I(fitted(m1)^2)) #Base model has HSK, p-value is low

        studentized Breusch-Pagan test

data:  m1
BP = 15.084, df = 2, p-value = 0.0005302
```

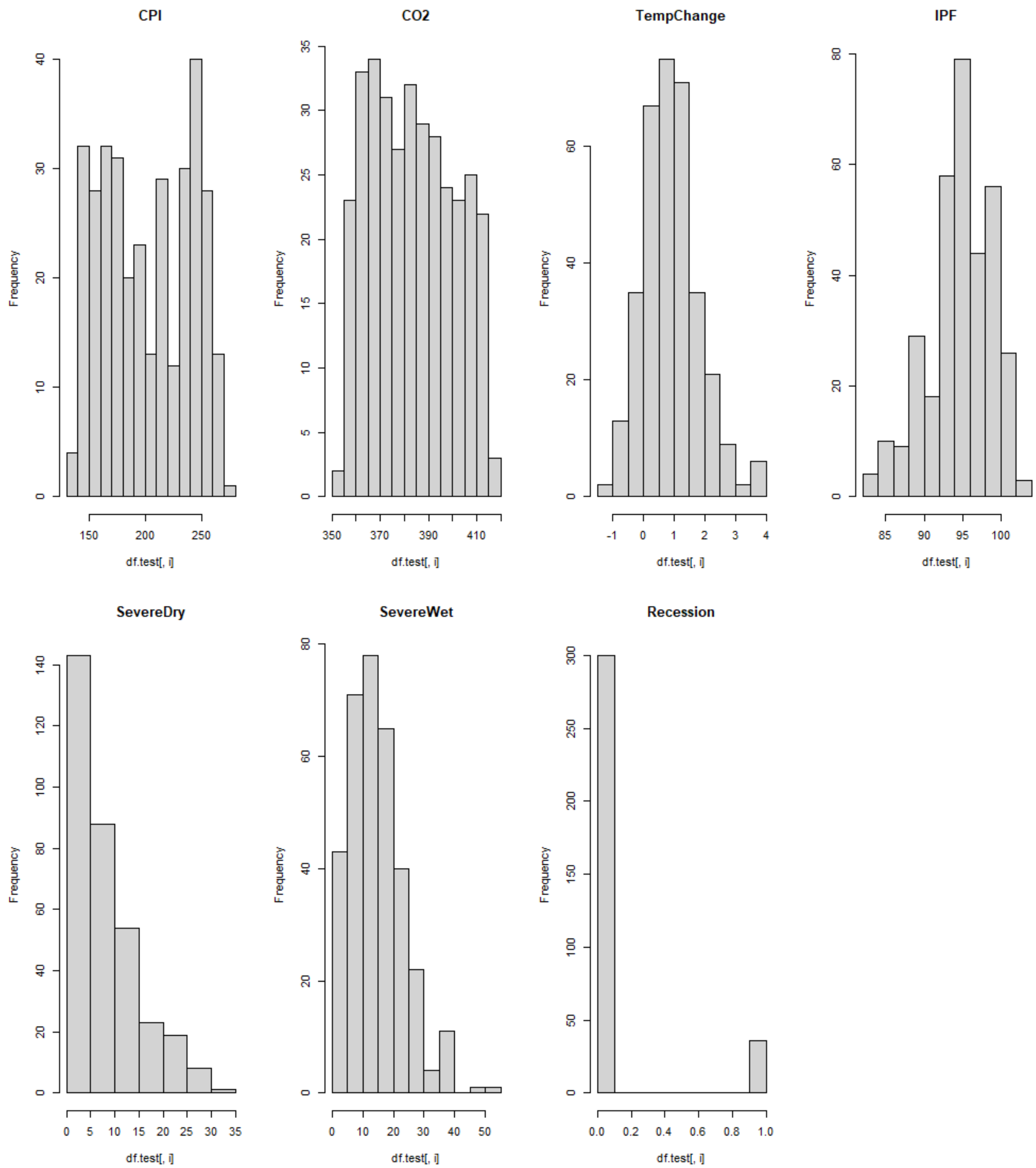
The initial model failed, heteroskedasticity is present.

b) Figure 1: Residual Plots of OLS Model



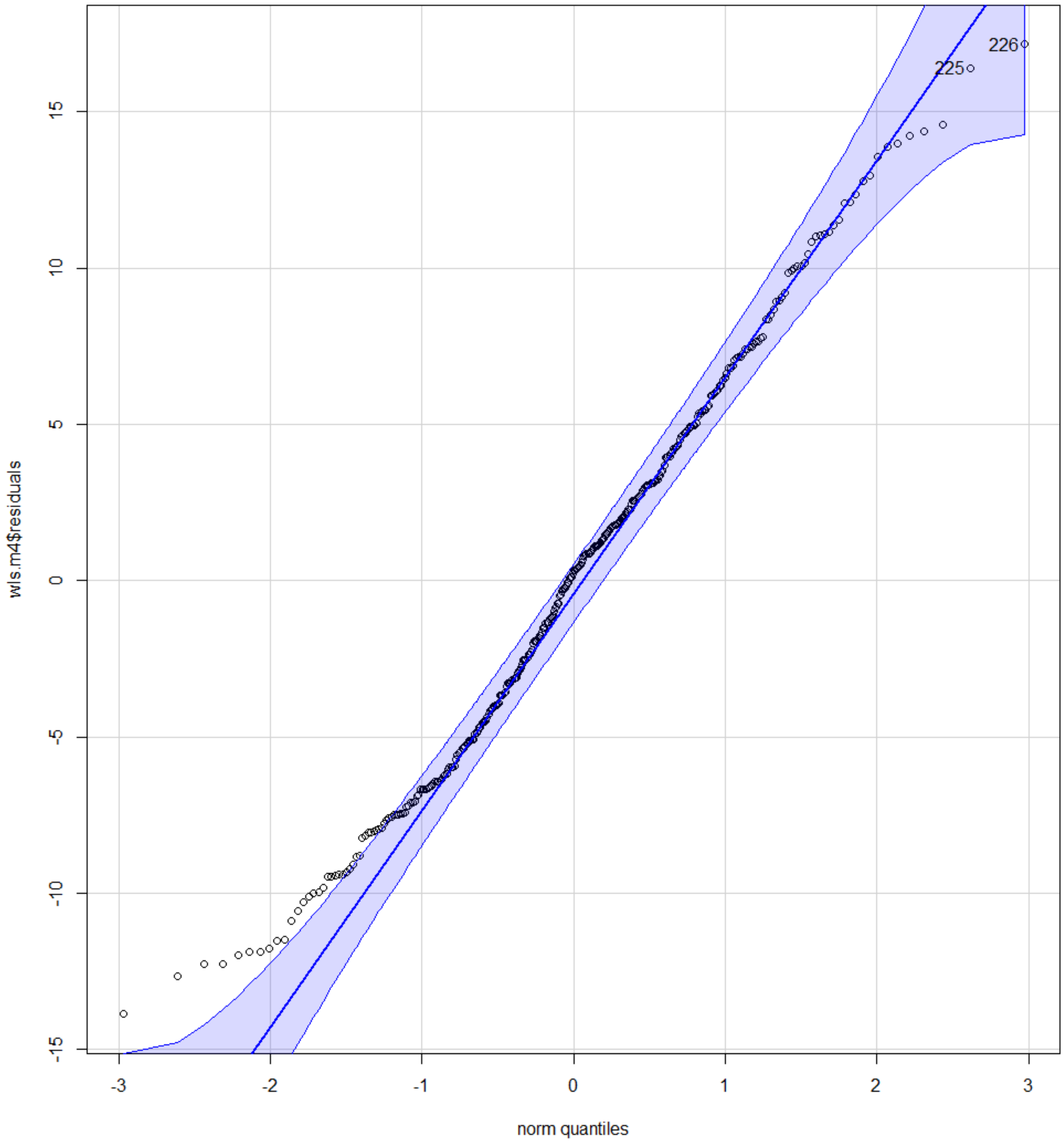
The White's Test observes that there is heteroskedasticity, and it can be observed in these residual plots. A WLS model would be more robust in regards to heteroskedasticity than OLS in this situation.

c) Figure 2: Histograms of all factors



Temperature and IPF are close to normal, and SevereWet has a slight shift. SevereDry, CPI, and CO2 are not normal. Due to the number of observations being so high, it is possible to ignore normality.

d) Figure 3: QQ-Plot of Final Model Residuals



Very close to normal, but there is a heavy tail in the lower quantiles. This heavy tail is why it barely fails the Shapiro-Wilk test.

e) Shapiro-Wilk Test of Normality

```
> shapiro.test(wls.m4$residuals)

        Shapiro-Wilk normality test

data:  wls.m4$residuals
W = 0.98904, p-value = 0.01258
```

Fails at an alpha = 0.05, passes for an alpha = 0.01 (significance of 99%).

VII. References

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