Aaron Chien

Professor Surro

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Inflation and Monetary Policy Post-Covid: Is the relationship between the Federal Interest Rate and Inflation still related after COVID-19?

Section 1 (Introduction):

In 2020, the global economy was hit by a respiratory disease called coronavirus, or more commonly known as COVID-19. Unlike previous recessions such as the Great Depression and the Great Recession, this recession was caused entirely by a pandemic instead of a financial/economic crisis and had severe effects on both the supply and demand side of the economy. The impact of this pandemic caused many consumers and buyers to avoid face-to-face contact and stayed indoors to prevent the spread of the virus, causing demand to severely drop. This in turn affected supply as production entirely stopped or was severely slowed (Goldstein) With this unfamiliar economic crisis, it brings up the question of how the FED can tackle the global economy and balance stimulating the economy versus risking hyperinflation. In the times following recovery from the pandemic and recession, we saw an influx of inflation (mainly food and gas prices, although the root cause of gas prices is most likely because of the Ukraine war) and a rapid rise of interest rates trying to bring inflation down. Examining the FED website, we see that the federal funds rate has increased to around 5 percentage points, the largest increase in this decade (FED). In the past three years, the global and US economy has experienced huge dips

and rises and examining the reason why, during the time of low production, the government issued many programs and policies with the goal to aid families and victims of COVID-19 by subsidizing money to be spent on essentials and to keep the financial market and business alive (Hayes). In the process of recovery after the pandemic, restaurants and hotels opened up again, and with the idea of remote work being introduced combined with extra money from stimulus packages, people were spending more in hopes of making up for "lost time". This is supported by the article written by the FED in which the goal of fiscal spending is to boost consumption, but oftentimes it leads to price tensions and inflation due to the supply side being unchanged (Soyres). Combined with the supply chain recovery, this created more price tensions. This was unforeseen by the FED and government which rapidly caused the increase in prices to be uncontrollable as the FED rapidly increased the interest rates in hopes of bringing inflation down. In this research paper, I question whether the methods of controlling the interest rates actually serve an effect on the economy in fighting inflation, or if it's causing a correlation in something else that may affect inflation. In summary, is monetary policy, controlling the interest rate of central banks, or the federal funds rate, still a viable method in handling inflation?

Section 2 (Literature Review):

To give a bit of background on the economy right now, the Federal Reserve has increased the interest rate by around 5 percentage points since 2022 following the aftermath of COVID in order to fight inflation. Inflation currently has increased from 1.23 in 2020 to hit 8 in 2022. To give context on these numbers, the Federal Reserve Committee tries to stay below a 2 percent inflation rate for a stable economy, and hitting 6 percentage points above that indicates that the US economy is unstable and our purchasing power is weaker. Before going into our own

research and conclusions, we need to examine what other researchers have found before and what conclusions they have drawn about inflation and how it affects the economy. In “Are High Interest Rates Effective for Stopping High Inflation? Some Skeptical Notes”, published by Guillermo A. Calvo, Calvo provides his research on how interest rates and inflation are correlated, or in the sense that they’re not directly correlated and interest rates are an indicator of something else. He explores how in the IS-LM model, a graphical representation of output and the interest rates, an increase in the interest rate actually leads to an increase in inflation. He further found out that increasing the interest rate leads to an expectation that inflation will increase, and this expectation in turn causes the IS curve to shift, leading to an increased interest rate and output. This shows how managing the inflation rate through monetary policy can cause a higher increase in inflation in which this pattern seems to be exhibited in our economy today (see section 4). Calvo further states that persistently high-interest rates may indicate a lack of confidence in the program and that high-interest rates may not lead to the conclusion intended. I also wanted to understand how the stimulus checks and monetary funding for businesses and people affected inflation as I read several articles on this issue in which high stimulation payments during a recession lead to inflation as these people would have extra money to spend once the recession is over. The research article, “Monetary Policy and Income Distribution in the COVID-19 Pandemic Crisis: A European Perspective”, by Sergio Rossi, explores how monetary policy during a crisis does not necessarily mean “improving the economy”. Instead, what Rossi discovered in his research was that the stimulus checks and programs that are implemented create price instability and only really benefit the upper-class and the wealthy. The central bank would then inflate asset prices, which is the inflation that we see after recovery from a recession. Rossi further suggests that central banks should focus on distributing the impacts of monetary

policies in order to reduce wealth disparities across the economy. So perhaps the reason why these policies are causing inflation is that it's benefiting the rich rather than the poor, so when times of crises are over, the upper and middle class who have not been quite hit by the recession could use the extra monetary benefits for spending, while poorer families would use the benefits for necessities. If this is true, we should see an overwhelming consumption in travel and outdoor dining, compared with grocery store prices. Now that we understand the impact of inflation and interest rates on the economy a little better, we can come up with ideas on how the interest rate plays a role in handling inflation, but what if the interest rate affects a different side of the economy? For this, I looked into the exchange rates as nominal prices may be changing but the real prices between different countries should translate, an apple in the US should cost an apple in Japan essentially. In the research article, "Exchange Rates, Interest Rates, and the Risk Premium ", by Charles Engel, he explores the impact of the interest rate on the exchange rates. The main reason I wanted to see this research was to explore the side-effects of how interest rates can not only affect inflation if it does at all, but I also want to see if there are any different factors or areas that it may have an unintended effect on. Engel states that when an asset becomes more valued for its liquidity, the country's currency appreciates and it eases inflationary pressure, which allows policymakers to lower interest rates. Higher interest rates are accompanied by higher liquidity returns, giving inventors an extra incentive to buy the high-interest rate asset. So if we increase the interest rate, people from other countries may have an incentive to invest, giving us "borrowed money" and we can lower interest rates after. An example Engel gave is that if the US real interest rate is high, the US home currency is weak. This opens a new perspective in which if we can further explore the patterns between interest rates and exchange rates, we can maybe get a closer idea of inflation, that inflation may not be a direct cause of the

interest rate, but also the exchange rates. Perhaps looking at other countries' exchange rates before examining our interest rates is the key to understanding the behavior of inflation. In the research article, “The Transmission of Monetary Policy Shock”, by Agrippino and Ricco, they discovered that expectations plays a large role in inflation and the impact of transmitting information from policymakers to investors affects their impulses of monetary behavior and thus further affects the central bank’s ability to influence monetary policy. Agrippino and Ricco also further explored how monetary shocks affect market prices and expectations can be correlated over time and contain information on current and past structural shocks. From the research these four authors did, we have a better understanding of how monetary policy affects the economy in which it may not work as intended in the long run, but because we’re looking at the COVID-19 recession, it showcases a different side of the economy in which we don’t know what the effects of a pandemic as previous recessions were rooted in the financial markets that the central bank can control with monetary policy, but a global pandemic is something that the government can’t control. The question left lingering is how the interest rate is affecting the economy after COVID-19 as the research before showcases how monetary policy may not be the best counter to inflation due to its effect on interest rates and inflation only decreasing in the short run. Based on the research by Agrippino and Ricco, we could explore the past impacts of monetary policies and how that past information can impact inflation, especially after a long period of economic downturn.

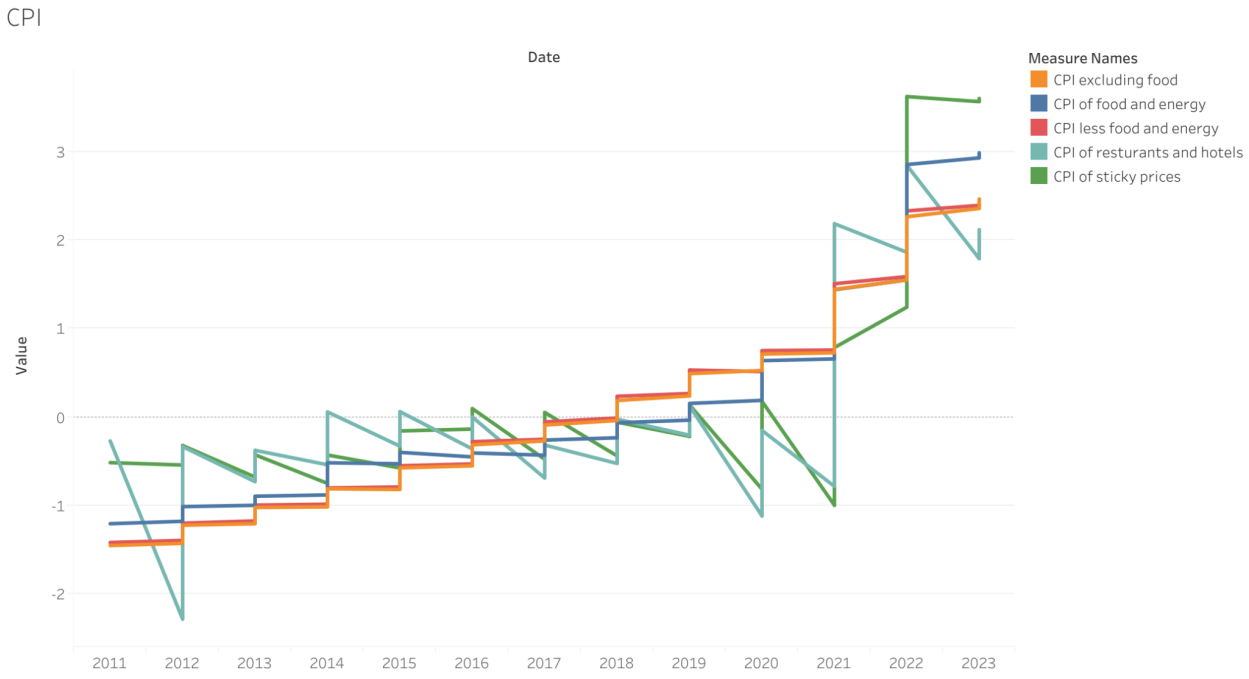
Section 3 (Ideal Research Design):

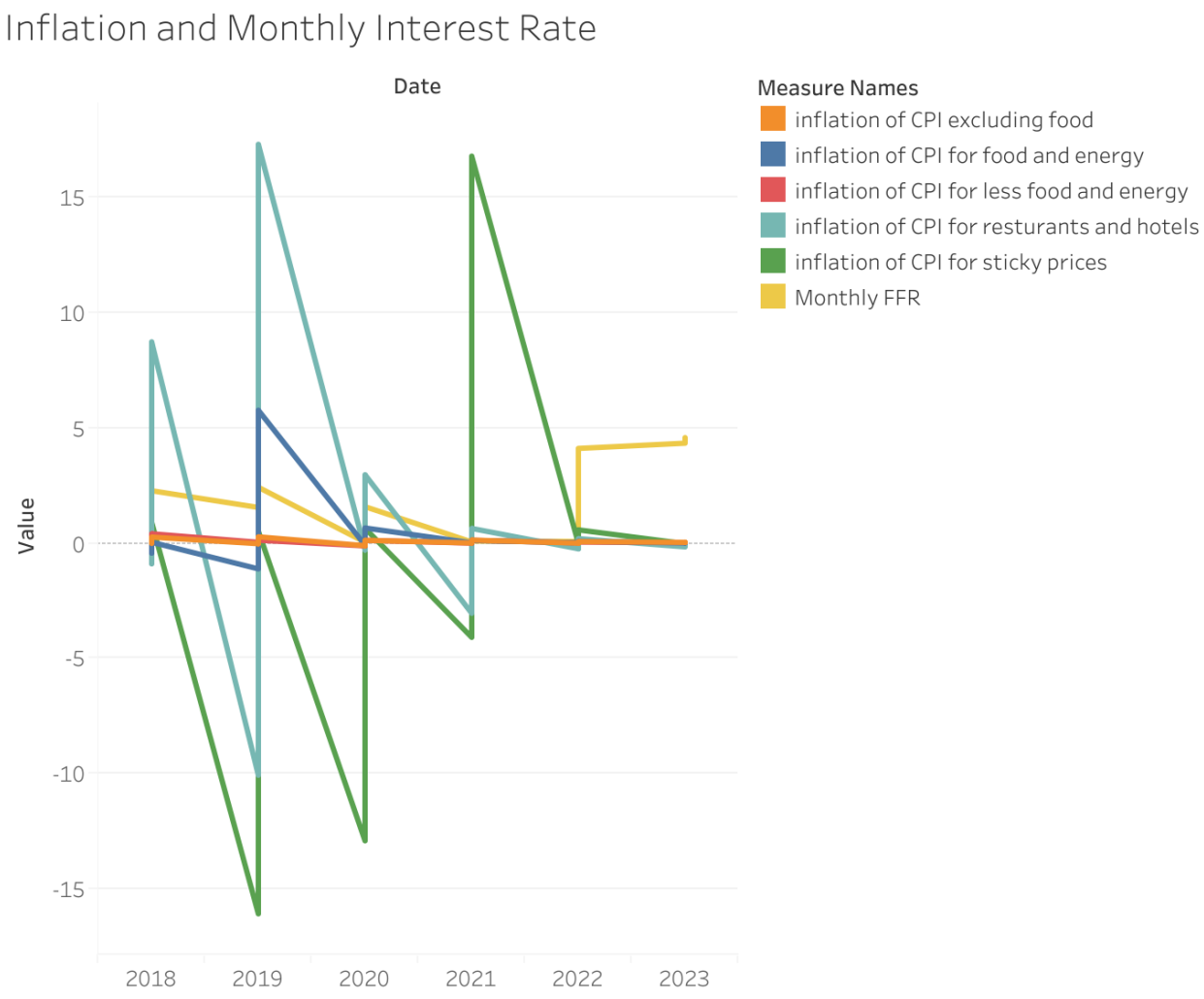
In order to analyze my research question of how monetary policy affects inflation after the effects of COVID, I need data on the federal interest rate that the Federal Reserve sets, a

measure of price levels (CPI or GDP), and exchange rates of other countries in order to understand if there are any side effects of monetary policy on other parts of the economy. These are all publicly available data, although messy, with a few steps of coding and cleaning would be able to analyze and create models to find correlations. However, this is not enough to fully understand the true effects as people are difficult to model, human behavior subjected to changes in the economy can be different on a case-by-case basis. Therefore, ideally, a dataset containing the people's expectations of inflation, their behavior, such as spending habits or traveling habits, pertained to expectations and realized inflation (actual inflation), and their actual behavior in realized inflation. This dataset brings in complicated questions as there are very few public datasets involving expectations and realized behavior and those that are available impose the risk of inaccuracy being a secondary source of data. But assuming perfect data, we can use the data to create time series models in which the information in the next period, how people would behave, how the interest rate will change, or how inflation would react to previous periods of interest rates, would depend on the information in the past. This would model an unexpected vs realized model in order to see correlations between periods and such and we would be able to see more relationships between interest rates, inflation and human behavior. Does the interest rate manipulate human behavior which controls inflation? Or does the interest rate control inflation which controls human behavior? These would be the ideal research questions to ask but given our limited data, we would stick to researching the effects of monetary policy on inflation post-covid.

Section 4 (Findings):

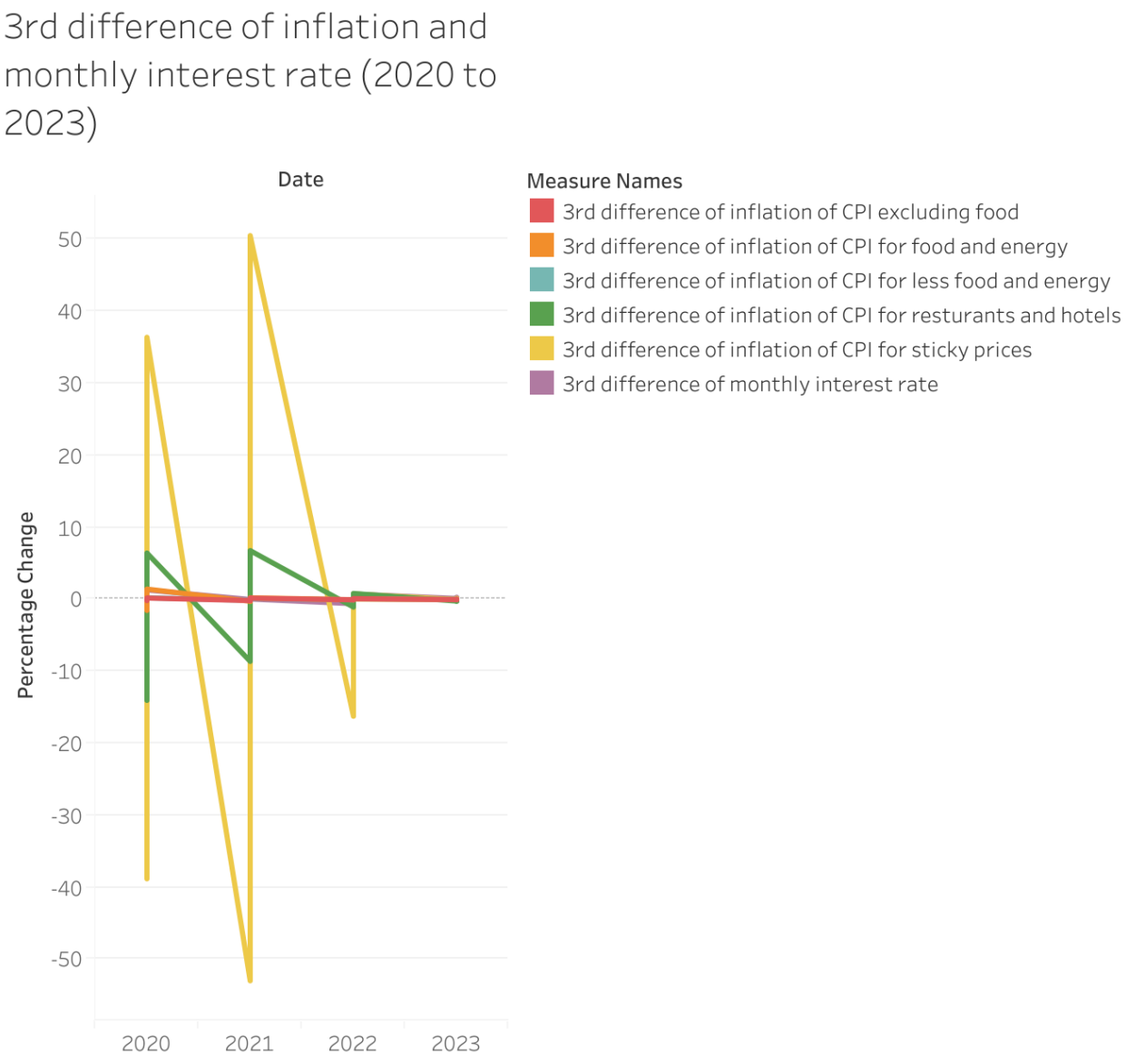
Before analyzing the data, I needed to first clean up the data and ensure the units were all the same. I uploaded the daily data on the federal funds rate as well as the monthly data for CPI on restaurants and hotels, sticky prices, not food and energy, food and energy, and excluding food and energy. Since the CPI was in monthly form, I converted the daily data of the federal funds rate by averaging the days of each month and dividing the data by that amount. I then converted the CPI into inflation by taking the percentage change. Examining the graph below, we see that there isn't a lot of straight correlation in between any of the inflation rates vs the federal funding rate, however, if we subsidize the data from 2020 to 2023, to see the correlation during the pandemic and after, we see there is a lot more trends following each other. One example is restaurants and hotels and sticky prices.



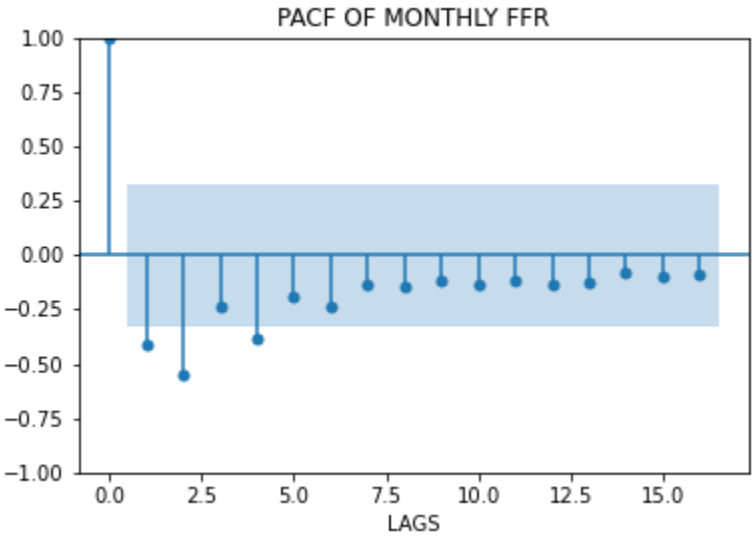


Since we're working with time series, I pooled all of the inflation columns and the interest rate columns into one data frame and created ACF and PACF graphs in order to determine which lag of information holds the most significance. Since we had five different kinds of inflation to research, I decided to showcase the best model and the methodology for that model as it was the same methodology for all of the other models as well. Our best model was the food and energy variable as it showed the most significant in the model. In order to perform time series analysis, I went with an ARDL model as it uses a combination of the AR model as well as some other explanatory lagged variables in order to make forecasts. I took a total of 3 differences of the entire dataset in order to make the variable stationary and performed a Dickey-Fuller test to

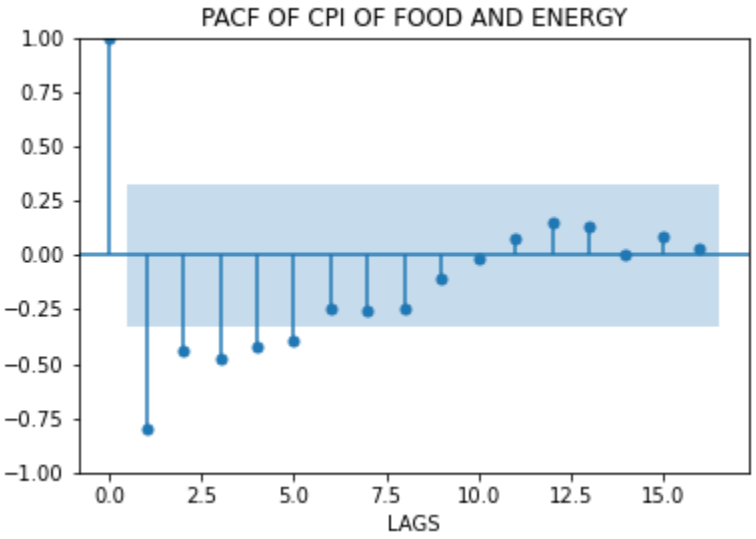
ensure that all the variables were indeed stationary (Stationary data essentially means that the mean and variance are constant across time so we can forecast without biases). As you can see in the graph below, the inflation for sticky prices is very spastic and hits both ends extremely, but if you were to take the average of it, it would even out to a mean of 0 and the variance would be constant. You can also see that the inflation for restaurants and hotels also follows the same trend, but in less extremes.



Since we're using ARDL, we need to use the PACF graph in order to determine the lags. The PACF model for the federal interest rate is:



As you can see from the graph, the lags that are the most significant are lag 1 and lag 2 as they pass the confidence interval (area shaded in blue) and provide the most amount of information in predicting the interest rate. Examining the PACF graph of CPI inflation on food and energy below, we can see that the most significant lags are lags 1, 2, 3, 4, and 5 as it exceeds the shaded blue area where it means insignificance.



In my analysis, I decided to only go up to 3 lags as I thought going beyond that was not necessary as the further periods we look back on, the more information we would need to predict the next period. I was able to create 6 different equations and all the variables were significant except for the intercepts so I decided to showcase the equation with the smallest intercept and an arbitrary random equation for comparison. Fitting an ARDL(1, 2) and ARDL(3, 2) where the first component is the y variable of inflation and the second component is the federal interest rate, we see that it results in

$$CPI_{FoodAndEnergy} = 0.0161 + -0.6540 \cdot CPI_{FoodAndEnergy(LAG1)} + 0.1640 \cdot FFR_{LAG2}$$

with the summary of significant variables shown below:

OLS Regression Results

Dep. Variable:	CPI_of_FoodEnergy	R-squared:	0.896
Model:	OLS	Adj. R-squared:	0.889
Method:	Least Squares	F-statistic:	129.1
Date:	Thu, 15 Jun 2023	Prob (F-statistic):	1.82e-15
Time:	00:09:24	Log-Likelihood:	29.962
No. Observations:	33	AIC:	-53.92
Df Residuals:	30	BIC:	-49.43
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	0.0161	0.018	0.901	0.375	-0.020	0.053
CPI(LAG1)	-0.6540	0.046	-14.199	0.000	-0.748	-0.560
FFR(LAG2)	0.1640	0.057	2.869	0.007	0.047	0.281

Omnibus:	6.224	Durbin-Watson:	1.519
Prob(Omnibus):	0.045	Jarque-Bera (JB):	4.613
Skew:	0.821	Prob(JB):	0.0996
Kurtosis:	3.812	Cond. No.	3.41

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

As for the ARDL(3, 2), the equation is as follows with the significant results shown below:

$$CPI_{FoodAndEnergy} = 0.0209 + -0.4492 \cdot CPI_{FoodAndEnergy(LAG3)} + 0.5515 \cdot FFR_{LAG2}$$

OLS Regression Results

Dep. Variable:	CPI_of_FoodEnergy	R-squared:	0.558
Model:	OLS	Adj. R-squared:	0.529
Method:	Least Squares	F-statistic:	18.97
Date:	Thu, 15 Jun 2023	Prob (F-statistic):	4.72e-06
Time:	00:09:24	Log-Likelihood:	6.1151
No. Observations:	33	AIC:	-6.230
Df Residuals:	30	BIC:	-1.741
Df Model:	2		
Covariance Type:	nonrobust		

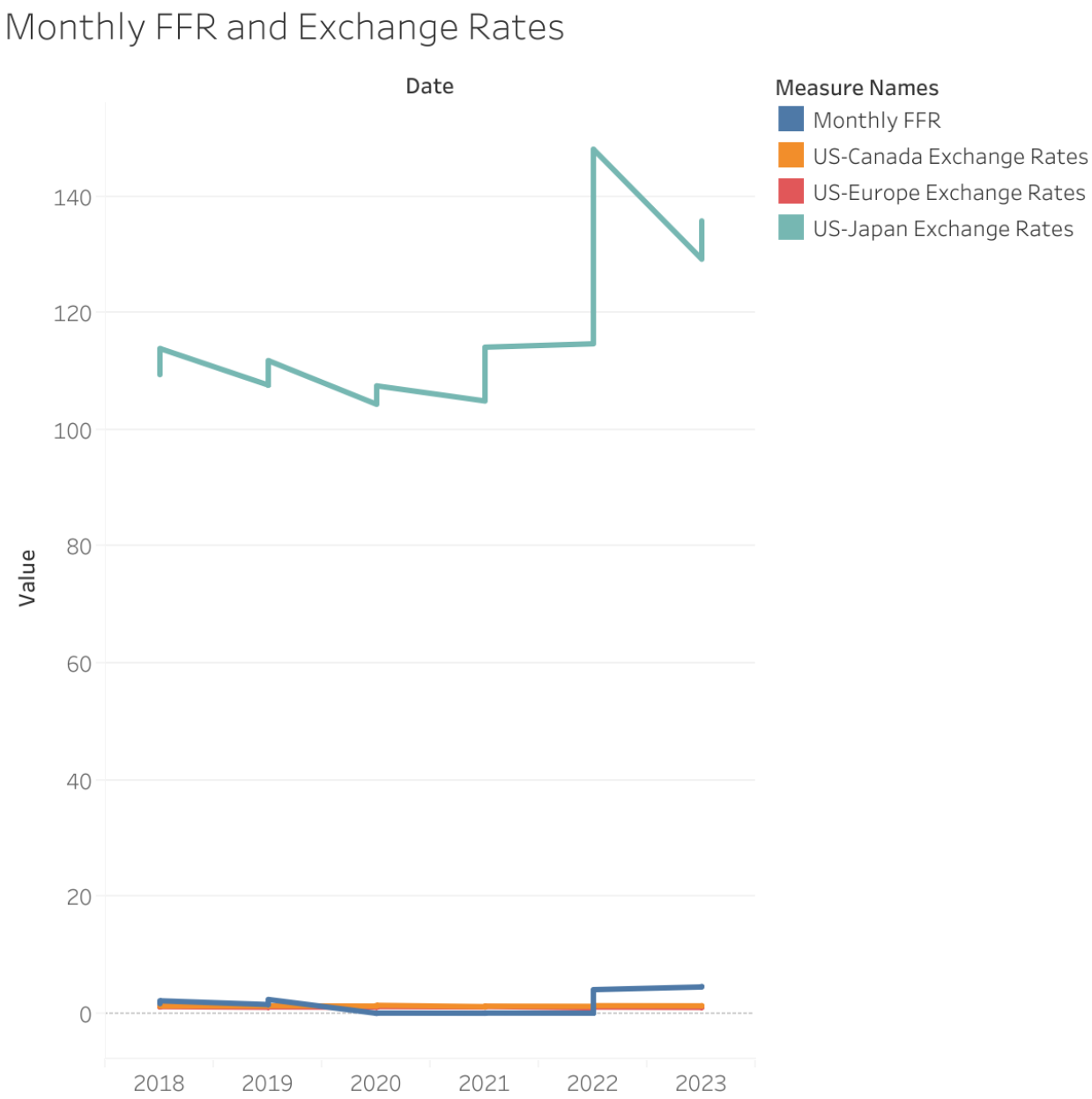
	coef	std err	t	P>|t|	[0.025	0.975]
const	0.0209	0.037	0.569	0.574	-0.054	0.096
CPI(LAG3)	-0.4492	0.091	-4.958	0.000	-0.634	-0.264
FFR(LAG2)	0.5515	0.116	4.763	0.000	0.315	0.788

Omnibus:	12.587	Durbin-Watson:	2.513
Prob(Omnibus):	0.002	Jarque-Bera (JB):	21.650
Skew:	0.751	Prob(JB):	1.99e-05
Kurtosis:	6.673	Cond. No.	3.28

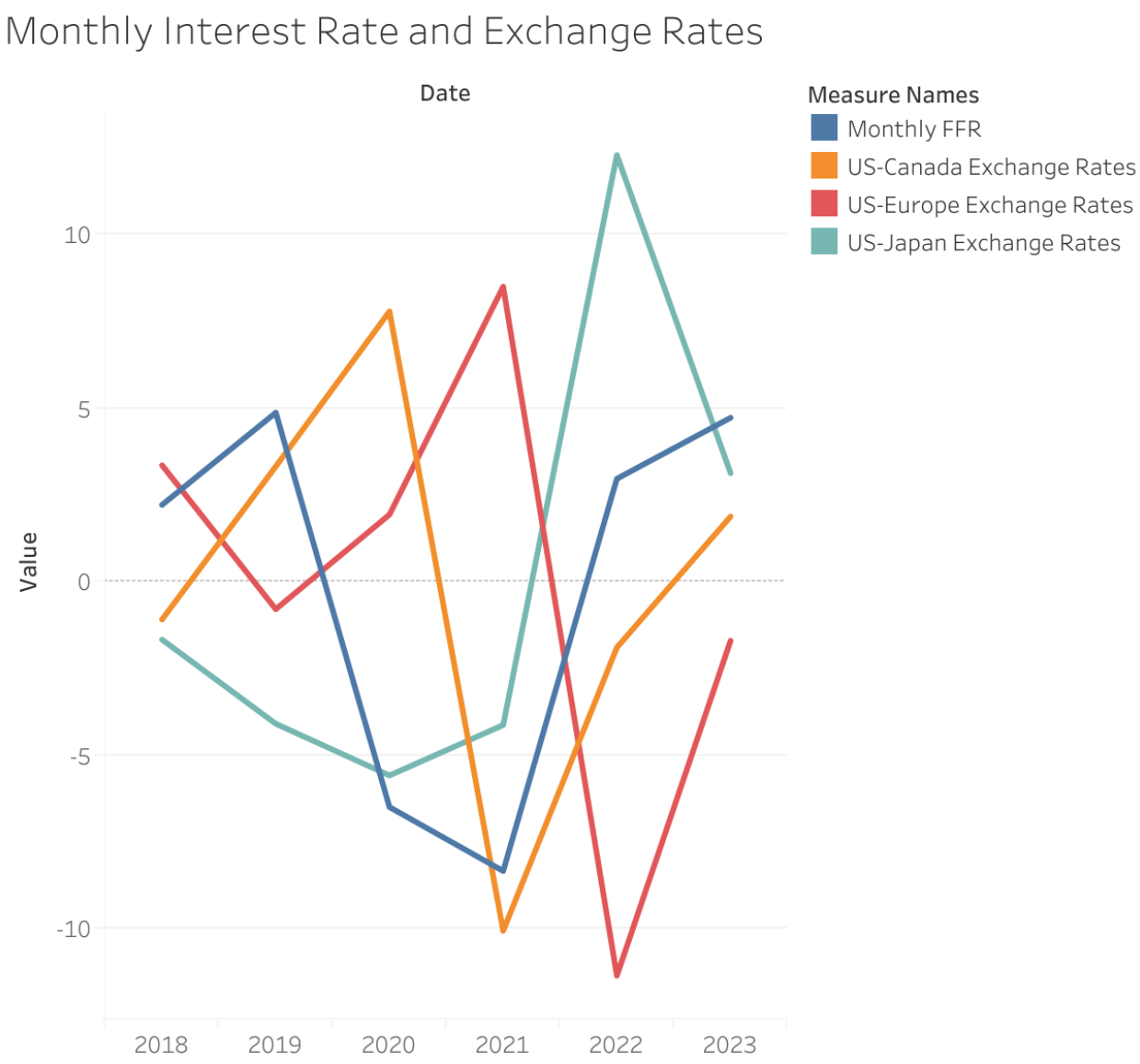
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

You can see that in both equations, the constant term is not very significant as it fails the 5% significant test. However, since both equations has both FFR and CPI variables to be significant and with a constant is somewhat to 0, we can just drop it so the equation becomes $CPI_{FoodAndEnergy} = -0.6540 \cdot CPI_{FoodAndEnergy(LAG3)} + 0.1640 \cdot FFR_{LAG2}$ for the ARDL(3, 2) model. This equation now represents the change in inflation for food and energy prices given the change in inflation 3 periods before and the change of the interest rate 2 periods before. From 2020 to 2023, the federal interest rates were the most significant in forecasting

inflation for food and energy. Moving on to examine the interest and exchange rates, we first plot the raw numbers in order to see any correlations and we see this graph:



We can see that the graph here is hard to understand and interpret due to the units of some exchange rates being 10x bigger than others. In order to remedy this, I used a normalization method to get all the units in the same unit and replotted them and the graph is here:



We can see that there is a lot more correlation and the graph is easier to read. From 2022 to 2023, there seems to be a straight correlation between all the exchange rate with the interest rate. However, when I started to perform time-series analysis on this data to see if the interest rate can predict the exchange rates, I discovered that there wasn't any significance in the interest rate predicting the exchange rates. Even after I performed dickey-fuller tests and made multiple differences, the ARDL models and significance tests showed that there was little to no predictability of the interest rate on the exchange rate. Here is one example of the ARDL(1, 1)

model between the interest rate and the US-European exchange rate where the first lag variable is the first lag of the european exchange rate and the second lag variable of the interest rate.

OLS Regression Results

Dep. Variable:	US_Euro_Exchange_Rate	R-squared:	0.339
Model:	OLS	Adj. R-squared:	0.300
Method:	Least Squares	F-statistic:	8.714
Date:	Thu, 15 Jun 2023	Prob (F-statistic):	0.000881
Time:	01:59:03	Log-Likelihood:	-28.812
No. Observations:	37	AIC:	63.62
Df Residuals:	34	BIC:	68.46
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	0.0087	0.091	0.096	0.924	-0.175	0.193
UEer(LAG1)	-0.6032	0.145	-4.154	0.000	-0.898	-0.308
FFR(LAG1)	0.2277	0.291	0.783	0.439	-0.363	0.818

Omnibus:	2.113	Durbin-Watson:	2.249
Prob(Omnibus):	0.348	Jarque-Bera (JB):	1.112
Skew:	0.060	Prob(JB):	0.573
Kurtosis:	3.841	Cond. No.	3.22

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

You can see here that the variables for the intercept, UEer (which represents the US-European exchange rate), and FFR (the interest rate), are all insignificant. Plotting a visual representation of the correlation, we can see that there are strong correlations across variables just from the graphical representation. Perhaps instead of forecasting inflation and exchange rates, we should've done correlation methods instead such as a polynomial or linear regression in which it predicts inflation and exchange rates in the same period rather than a period ahead.

Section 5 (Reflection):

In conclusion, we still see from the data that monetary policy is working for a sector of the economy and food and energy prices do show correlation with that and since grocery store prices have been on the rise and the FED is attempting to maintain a control over those prices, it's a good sign that there is control. However, this is not the full picture as there are many questions that still need to be answered such as external factors that are the causes of inflation in food and energy and if human behavior plays a part. The reason why this research question would possibly never have a full conclusion is because human behavior is difficult to model. We as a species are subject to entropy and randomness at some points and would behave in ways unexpected, which is a flaw in the model. We are able to research the quantitative side of the economy, watching the numbers, finding holes and areas of unanticipated shocks to understand the reason why these spastic movements are happening. The economy depends on the people and their movement as well, which is something that I was unable to factor in my research. How does human behavior and our expectations of their behavior change and how does that affect the economy and inflation? Given more time, I would've liked to research more on that but it would take possibly years to collect data across states and cities, analyze and clean the data, and then process it to be researched. There are also datasets out there of human behavior, but those imposed risks of biases and inaccurate sampling. I do believe that this model would be achievable on a smaller scaler, perhaps maybe a city or a state, but expanding the research to be across states and cities to encompass everyone as an accurate representative whole of the US economy would be near impossible as it requires depths of research and variables to achieve. With technology and more research on machine learning and algorithmic models however, compared to what has been done in the past, perhaps with the help of computer science, AI, and

statistics, a new type of model beyond a simple ARDL model would be theorized and applied with high accuracy of predicting inflation.

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