Inflation Drivers: A Post-COVID Analysis

by

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Department of Statistical Science
Duke University

Defense Date: April 1st, 2025

Approved:

David Banks, Advisor

Alex Volfovsky

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Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Statistical Science in The Graduate School of Duke University
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ABSTRACT

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Abstract

The post-COVID inflationary surge and subsequent disinflation have generated significant debate regarding their causes and policy implications. This paper assesses the drivers of inflation from the onset of the COVID-19 pandemic through the subsequent disinflation, with a particular focus on the sharp decline in inflation from June to July 2022. Using the Consumer Price Index (CPI), this analysis evaluates six primary explanations for inflationary trends: energy price shocks, supply chain disruptions, firm pricing power, wages and worker bargaining power, inflation expectations, and government stimulus.

A Rolling-Window Granger Causality model is employed to assess the temporal relationships between inflation and key economic indicators, allowing for a structural break in the data coinciding with initial stay-at-home orders. This approach identifies gasoline prices, real personal expenditures, and the labor leverage ratio as significant contributors to the initial inflationary surge, while the Federal Funds Rate exhibits a delayed relationship with disinflation. However, no single variable or event is found to explain the sudden drop in inflation in the summer of 2022. A time-interaction linear model is further applied to test the impact of identified economic events on inflation trends, revealing a lack of support for the common narrative that corporate profits, consumer income, or government transfers significantly drove inflation.

The findings suggest that inflation was largely driven by real economic shifts rather than speculative price-setting behavior, and that Federal Reserve policy may not have been the primary driver of disinflation. These results highlight the need for a more nuanced understanding of inflationary pressures, particularly in the face of supply-side shocks and labor market dynamics, and underscore the importance of robust methodological approaches to economic policy evaluation.

Dedication

In loving memory of Bo Gold.

And to Eleanor Gold, my parents, stepparents and the Gold family, for your support. To my brother, for being my best ally and rival. And to Riven, Max, Prince and Rambo for reminding me to take breaks.

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1. INTRODUCTION

1.1 Background

The Coronavirus SARS-CoV-2 (COVID) was first identified in humans in December 2019, with the first international cases identified before the end of the year. In response to the rapidly spreading outbreak, on March 19, 2020, California became the first state in the US to issue stay-at-home orders for workers deemed non-essential, New York and Illinois would do the same in the following days. As the virus spread, so did efforts to stop it. In a matter of days, over ten million people lost their jobs, the S&P 500 lost roughly 20% of its value and shortages of household goods were common.

This represented a period of uncertainty, fear, and interruption to daily life for almost every household in the US. Inflation, as measured by the Consumer Price Index (CPI), dropped significantly. Month-over-month annualized percentage change (M/M) dropped from 0.6% in February to -5.3% in March to -9.1% in April. The year-over-year percentage change (Y/Y) in CPI hit its lowest point in several years in June with 0.2%, but a recovery was already underway. When the National Bureau of Economic Research Business Cycle Dating Committee convened in late June, they announced that the US economy had already experienced the shortest recession it had ever seen (February to April 2020).

The expansionary period following the end of the 2008 recession until the start of the 2020 recession (May 2009 through January 2020[1]) represented a period of price stability with mean Y/Y of 1.7% and standard deviation 1.0%. The ten months that followed this announcement seemed to mark a return to that previous regime with no month seeing a Y/Y change greater than 1.5 times the previous standard deviation away from the previous mean.

[1] As determined by the NBER Business Cycle Dating Committee

It is worth noting that since Y/Y is equivalent to the geometric mean of the last twelve months of M/M changes, one could argue that data from the initial months of the pandemic is obscuring some greater trend; however, over this same period M/M stayed within 2 times its previous standard deviation of its previous mean.

This seeming return to normal was only broken in April 2021, when Y/Y reached 4.1% and M/M hit 8.4%, highs for both measurements not seen in over a decade. This marked the beginning of the 2021 inflationary surge. Inflation trended upward over the following fifteen months, until June 2022 when Y/Y was 9.0% and M/M was 16.7%. There was a fear among some of what double-digit Y/Y inflation would mean for the economy at a time when most were still trying to determine what post-COVID life would look like.

The next month, M/M saw a 17.2% drop (from 16.7% to -0.5%), the largest one-month drop in M/M inflation since 1973. August reported 1.8% M/M. The next two months were 5.3% and 6.5% M/M, but the two months after that were 3.0% and 0.4%. As the Y/Y measure of inflation (recall that it is a moving-average of M/M) slowly crept back toward the Federal Reserve's long-run target (2.0%), M/M seemed to have returned near to its pre-COVID distribution. That is, pre-COVID mean 1.8% and standard deviation 2.3% compared to post-peak mean 3.0% and standard deviation 1.6%. By June 2023, Y/Y no longer included data from the previous June and so got below 3.2% for the first time since the start of the inflationary surge. The months that followed suggest a new distribution for Y/Y (mean 3.1% and standard deviation 0.4%).

1.2 Motivation

This research was motivated by two observations:

1. The controversial nature of inflation attribution in popular coverage: In a discussion of the candidates in the US presidential race, *The Economist* wrote in its August 22nd, 2024, edition that "the claim of price-gouging is simply not supported by the evidence, but it

nonetheless erodes the faith in open markets that makes America prosperous." Earlier that month, the Federal Trade Commission filed a motion to block the merger of grocery chains, Kroger and Albertsons. In the filing, the FTC cited internal communications and testimony that Kroger had raised prices beyond cost inflation, leading to increased profits while contributing to the inflation experienced by consumers.

The same week as *The Economist* piece, the Department of Justice filed a civil antitrust lawsuit against RealPage, alleging that the company's app had become a platform for rent price-fixing.

Therefore the question becomes: what claims does the data actually support?

2. There seems to be a considerable lack of discussion and research directed at toward the sudden drop in inflation described previously (the drop from June to July 2022). Was it the result of policy intervention? Did it come down because the pressures that accelerated it had subsided, or did the downward pressure finally dominate?

Finding data-backed answers to these questions would expand our understanding of inflation and how the economy adapted to the post-COVID world. Moreover, it could potentially inform future inflation mitigation policy decisions.

2. DATA

For this analysis, we chose to focus on inflation as recorded by the Consumer Price Index as it is the most widely cited measure of inflation, and its itemized tables and special aggregates provide useful insight.

We can use these tables and special aggregates to inform how we choose to structure our analysis. Using a methodology published by the Bureau of Labor Statistics, we can decompose the trends in the top-line All Items categories into four categories: Food, Energy, Shelter, and All Items less Food, Energy & Shelter ("All Other Items" in the chart). Since the categories must sum to 100% at each time step, a dramatic change in one category is echoed in the opposite direction in the other categories. This is what we see in the plot below. When Energy prices collapsed amid the initial stay-at-home orders it exerted significant negative pressure on the trend in All Items inflation (the top-line measurement). Since the decomposed trend must sum to 100%, the other three lines spike upward to compensate.

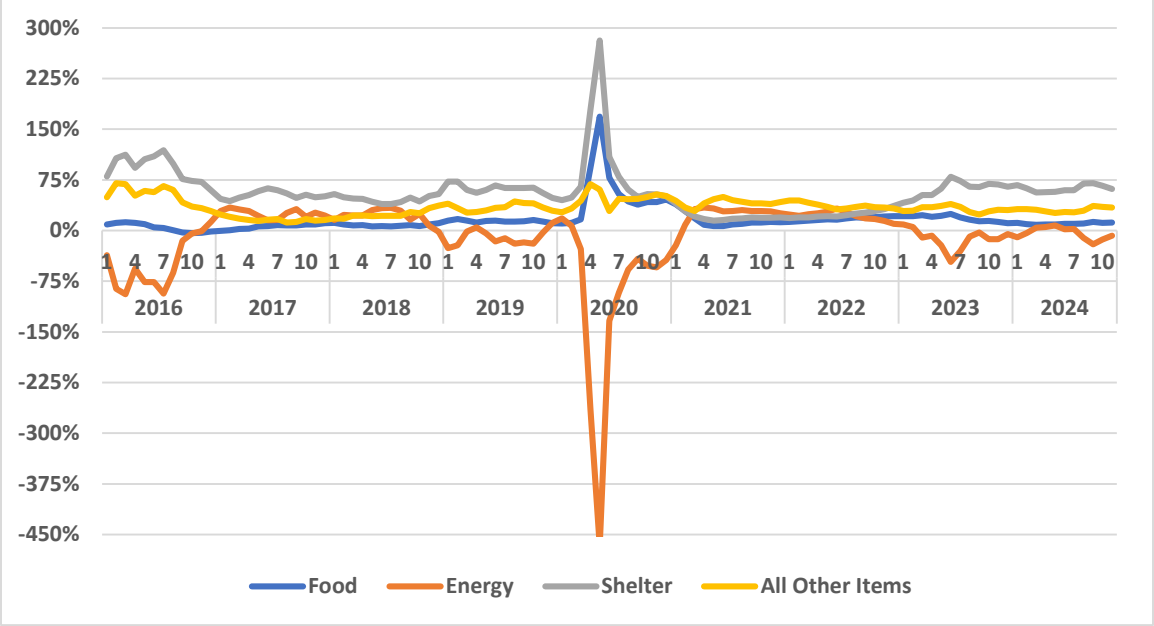

Figure 1: Contribution to Inflation by Major Components

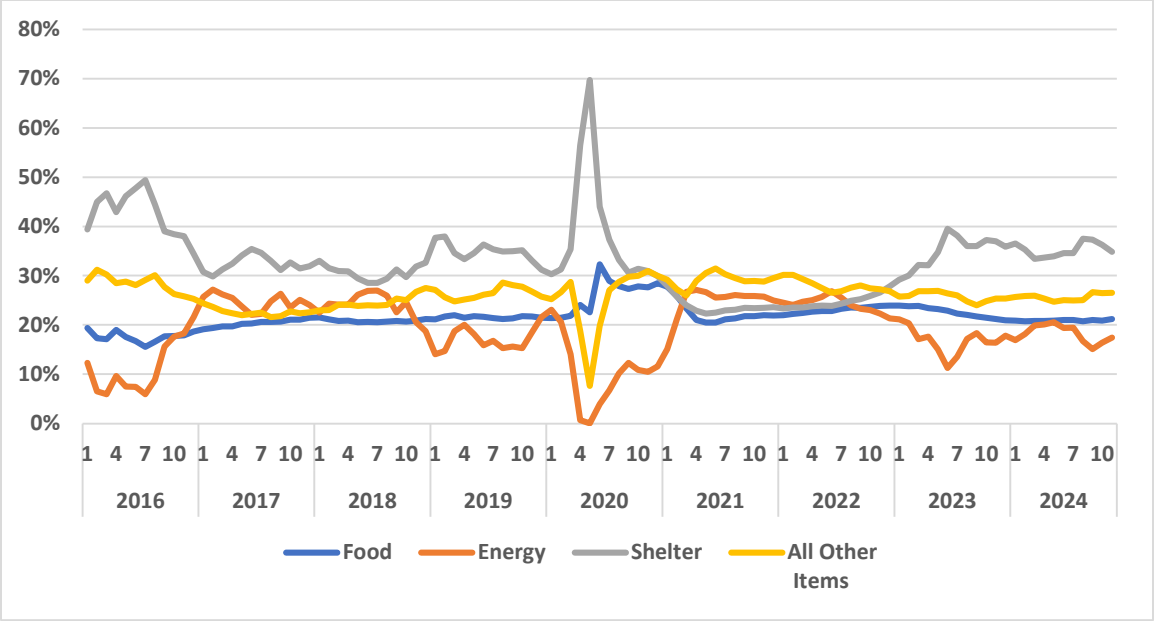

Figure 2: Contribution to Inflation by Major Components, re-scaled with SOFTMAX

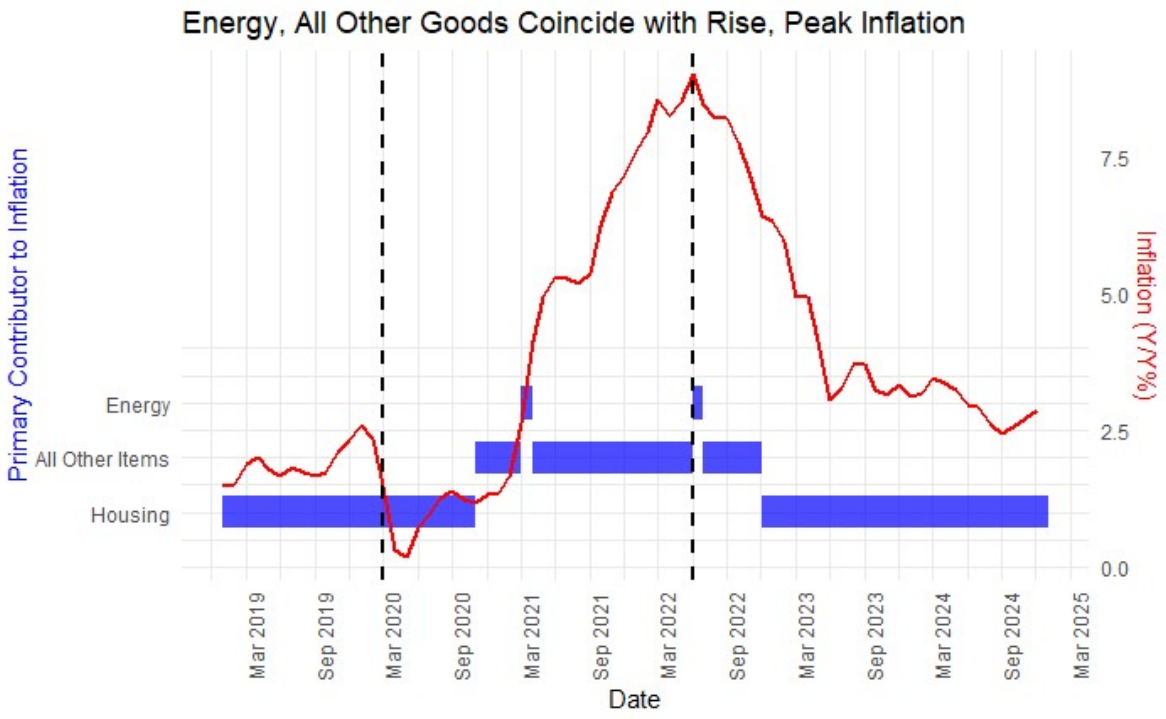

Figure 3: Primary Contributors to Inflation Over Time

2.1 Explanations

2.1.1 Energy

At the start of the pandemic, multiple factors combined to send the price for West Texas Intermediate crude oil futures to -$37. While the price recovered quickly back to approximately $30, this represented a problem for oil producers. The estimated break-even price for oil production in the US is around $50. Prolonged periods under this price cause wells and production facilities to shut down. While production can be scaled back up when prices are above $50, this is a process that can take months. The 2020 price shock could have caused producers to cut production and keep it low until they feel prices are high enough to risk scaling production back up. Because gasoline touches almost everything in CPI, it is a strong candidate for an explanation.

We measure this effect through the national average price of regular unleaded gasoline as reported by the US Energy Information Administration. We also identified events relating to price war, negative oil futures price, OPEC decisions, the Russian invasion of Ukraine and the Biden administration's steps to reduce gas prices.

2.1.2 Supply Chain Difficulties

Supply chains struggled to adapt to the change in consumer behaviors brought on by COVID and stay-at-home orders. The shift in what needed to go where caused backlogs in ports, shipping container shortages in some places and abundance in others. These difficulties translated to increased freight costs. Since so much of the US economy travels by ship or truck, we are interested in evaluating to what extent these disruptions contributed to inflation.

We measure this effect through a water freight price index, a truck freight price index, and the novel Global Supply Chain Pressure Index (Benigno et al, 2022) which, among other information, captures changes in shipping container prices. The events we identified were the initial stay-at-home orders, the Suez Canal blockage, and the Inflation Reduction Act.

2.1.3 Profits & Price Gouging

As consumers and firms learn to navigate the post-COVID economy, it is possible that some consumers have an increased willingness to pay for goods and services that they believe could be in short supply. In a similar sense, some consumers may have become less price elastic, seeing price fluctuations as part of the new normal. Firms could capitalize on this by increasing prices in excess of changes in their costs.

To capture this effect, we identified indicators related to corporate profits, inventories, the ratio of inventories to sales, and the producer price index. The events we identified are the series of stimulus payments, the Federal Reserve's messaging and rate policy, the Biden administration voicing a willingness to levy a windfall profits tax, and the previously mentioned FTC lawsuit.

2.1.4 Wages & Worker Power

Discussions of inflation often center around the topic of the wage-price spiral. That is, the feedback loop that occurs when firms increase prices to cover the cost of increased wages but then workers ask for increased wages to cover the cost of increased prices. Thus, an inflationary feedback loop can spin out of control. We measure the change in wages over this period with real personal income and the employment cost index, measure workers' ability to demand higher wages through the novel labor leverage ratio (Sojourner & DiVito, 2022), and measure to what degree disinflation is associated with a breaking of the wage-price spiral through total unemployment. The events we highlight are the four stimulus bills and the passage of the Inflation Reduction Act.

2.1.5 Expectations

Expectations are a critical aspect of any market. Expectations of future inflation lead consumers and firms to make decisions that cause inflation in the near-term. We capture this

effect from two sources: the consumer survey of inflation expectations conducted by the University of Michigan and inflation expectations as derived from bond prices. The events we identified are the Federal Reserve's messaging and rate policy changes.

2.1.6 Public Policy Considerations

In the twelve months following the initial lockdowns in the US, the federal government released three rounds of stimulus to households, and one directed at small businesses. These immediate injections of cash, meant to assist consumer spending through the difficulties of the pandemic, could have contributed to the inflationary surge. The sudden increase in incomes could have translated to a sudden increase in spending and thus increased prices through scarcity. There is also the argument that these bills increased the amount of currency in circulation, thus leading to inflation through the depreciation of the dollar.

In addition to testing government policies for causing inflation, we also want to test the efficacy of governmental policies meant to mitigate inflation. It is the "dual mandate" of the Federal Reserve to balance low unemployment and low inflation. The Federal Open Market Committee (FOMC) at the Federal Reserve has two main tools for accomplishing this: messaging and rate policy. Due to the economic consequences of adjusting the Federal Funds Rate, the FOMC prefers to try to accomplish its goals by shifting expectations via its messaging. If that proves insufficient, then they will increase interest rates.

We capture the intended and unintended effects of government policy through government transfers to persons, real personal expenditures, the Federal Funds Rate, money supply and velocity of money. The events we identified are the four stimulus programs, the first use of "transitory" messaging, the FOMC communicating a readiness to increase rates and the Inflation Reduction Act.

2.2 Events

The table on the following page lists all the events we identified as potentially relevant to this analysis. Since this analysis is conducted with at most monthly frequency, we will be unable to differentiate the effect of events that occur in the same month. To that end, some explanations have more than one event identified for a given month (see "Initial Stay-at-Home Order" and "CARES Act" both occur in March 2020, and are identified as potentially effecting Expectations).

The table also includes event dates and which explanation the event could be relevant to. Rows are shaded by month. Further details about each variable in this analysis are included in the following subsection.

Table 1: Claims & Events with Possible Correlation

EXPLANATION:		ENERGY	SUPPLY CHAIN DIFFICULTIES	PROFITS & PRICE GOUGING	WAGES & WORKER POWER	EXPECTATIONS	PUBLIC POLICY CONSIDERATIONS
EVENT	DATE						
Saudi-Russian Price War	2020/03/08	•					
Initial Stay-at-Home order in NYC	2020/03/22		•			•	
CARES Act (Stimulus 1)	2020/03/27			•	•	•	•
Negative Oil Price	2020/04/20	•					
Paycheck Protection Program	2020/04/24			•	•	•	•
CA Act (Stimulus 2)	2020/12/27			•	•	•	•
ARP Act (Stimulus 3)	2021/03/11				•	•	•
Fed Uses "Transitory" Messaging	2021/03/17			•		•	
Suez Blocked	2021/03/23		•				
Biden releases 50M barrels from SPR	2021/11/23	•					
Communicated Readiness to Increase Rates	2022/01/26			•		•	•
Russian Invasion of Ukraine	2022/02/24	•	•				
Biden releases 30M barrels from SPR	2022/03/01	•					
Biden releases 1M barrels per day from SPR	2022/03/31	•					
Inflation Reduction Act	2022/08/16		•	•	•	•	•
Biden Threatens Windfall Tax	2022/10/31	•		•			
OPEC Extends Production Cuts	2023/11/30	•					
FTC Sues to Block Grocery Merger	2024/02/26			•			

2.3 Data & Sources

Table 2: Data & Sources

Name	Frequency	Units	Role	Source
Consumer Price Index, All Items	Monthly	Index	Dependent	BLS
Gasoline, Regular	Weekly	Nominal $	Energy	EIA
Lumber Price Index	Monthly	Index	Housing	BLS
Median Price Per Square Foot	Monthly	Count	Housing	REAL
Median Days on Market	Monthly	Count	Housing	REAL
Active Listings	Monthly	Count	Housing	REAL
Renter Occupied Housing	Quarterly	Count	Housing	CB
Rent of Primary Residence	Monthly	Index	Housing	BLS
Water Freight Index	Monthly	Index	Supply	BLS
Truck Freight Index	Monthly	Index	Supply	BLS
Global Supply Chain Pressure Index	Monthly	Index	Supply	FRNY
Corporate Profits	Quarterly	Nominal $	Profits	BEA
Total Inventories	Monthly	Nominal $	Profits	CB
Total Inventory to Sales Ratio	Monthly	Ratio	Profits	CB
Producer Price Index Less Fuel	Monthly	Index	Profits	BLS
Real Personal Income	Monthly	Real $	Wages	BEA
Employment Cost Index	Quarterly	Index	Wages	BLS
Labor Leverage Ratio	Monthly	Ratio	Wages	*
… Total Quits	Monthly	Count	Wages	BLS
… Total Layoffs	Monthly	Count	Wages	BLS
Inflation Expectation, Derived from Bonds	Monthly	Percent	Expect.	FRCL
Inflation Expectation, Consumer Survey	Monthly	Percent	Expect.	UM
Government Transfers to Persons	Quarterly	Nominal $	Policy	BEA
Real Personal Expenditure	Monthly	Real $	Policy	BEA
Federal Funds Rate	Daily	Percent	Policy	FRBG
Total Unemployment	Monthly	Count	Policy	BLS
M2 Money Supply	Monthly	Real	Policy	FRSL
Velocity of Money	Quarterly	Ratio	Policy	FRSL

BEA: Bureau of Economic Analysis**,**
BLS: U.S. Bureau of Labor Statistics**,**
CB: U.S. Census Bureau**,**
EIA: U.S. Energy Information Administration,
FRBG: Federal Reserve Board of Governors**,**
FRCL: Federal Reserve Bank of Cleveland**,**
FRNY: Federal Reserve Bank of New York**,**
FRSL: Federal Reserve Bank of St. Louis**,**
UM: University of Michigan**,**
REAL: Realtor.com,
***** Composite of following variables

3. METHODOLOGY

3.1 Establishing Stationarity

We begin the analysis by establishing with which transforms of CPI we find evidence of stationarity. Throughout this process of establishing stationarity, we do not use the Augmented Dickey-Fuller to test for evidence of a unit-root if a transform does not result in lower variance. This is done to prevent the over-application of transforms and unnecessary tests reducing the power of this analysis. Once we have found one or more transforms with significant evidence of stationarity, we evaluate each of the independent variables with the same (or equivalent) transforms. We continue the analysis with the transform that causes both CPI and a given independent variable to be stationary simultaneously. If we find evidence that more than one transform produces a stationary process, then we continue with the transform that provides the lowest ADF-statistic in the independent variable.

As we will discuss further in the Results section, we found evidence that the COVID lockdowns represent a structural break in the underlying data generating process. Since we have compelling reason to believe that there is a structural break in the data, then the conventional Granger Causality is not appropriate. Moreover, since we are limited in the number of observations following the initial stay-at-home orders—up to present day—any modeling approaches that assume a partition at the break will be limited in power. Thus, we deploy the Rolling-Window Granger Causality model as it allows for breaks in the data without the same loss of explanatory power.

3.2 Rolling-Window Granger Causality Model

As previously mentioned, we deploy the Rolling-Window Granger Causality model, because we have reason to believe that there is a structural break in the data. Moreover, since the rate of inflation likely has many contributing factors but might only be dominated by a few of

those factors at a time, then the Rolling-Window Granger Causality model has the additional benefit of capturing how Granger-causality might vary with time.

After establishing with which transformation an independent variable and CPI inflation are simultaneously stationary, we fit the Rolling-Window Granger Causality model over the full range of data. Since we are still faced with a limited number of observations, we try to reduce the likelihood of a type 1 error by fitting the Rolling Window Granger Causality model over three window lengths for monthly data (12 months with 1 lag term, 36 months with 2 lag terms and 60 months with 3 lag terms), and two window lengths for quarterly data (12 quarters with 1 lag term and 20 quarters with 2 lag terms). We reject the null hypothesis in favor of evidence of Granger Causality for any period where at least two of the models return p-values less than 0.01 for two or consecutive months. Appendix A shows all Rolling Window Granger Causality plots used in this analysis. For those variables that we can find intervals of significant Ganger Causality, we are able to compare those intervals against our list of potentially correlated events.

3.3 Time-Interaction Linear Model

Once we have determined which of our independent variables, we have significant evidence of a Granger causal relationship and over what intervals, we compare those intervals with the list of events relevant to that variable as previously described. For the dates that occur within one of the Granger causal intervals, we fit a linear time-interaction model for Y/Y CPI and the annual rate of growth for the independent variable with the knot at that date. Supposing a given event has a causal relationship with inflation via the independent variable as prescribed in the associated explanation, then we would expect to see a significant change in the trend in inflation and the independent variable coinciding with the date of that event.

For example, if one or more of the stimulus programs had a depreciating effect on the currency, then we would not only expect to see a change in the trend in inflation coinciding with a stimulus payment, but also a change in the trend of the M2 money supply at the same time. In

this case, we would expect to see significant positive time-interaction coefficients for both variables. Therefore, by contraposition, failing to find evidence of a significant time-interaction coefficient with sign that agrees with the explanation for both inflation and the independent variable would provide a strong argument that the event in question did not have the causal effect as hypothesized.

4. RESULTS

4.1 Stationarity

The following table shows the transforms of CPI we tested for stationarity and over what interval. Note that significance changes based on which interval is tested. This provides compelling evidence that COVID represents a structural break in the underlying data generating process for inflation.

Table 3: CPI Stationarity

		Full Jan. 2010 to Jan. 2025	**Recovery** Jan. 2010 to Jan. 2020	**COVID** May 2020 to Jan. 2025
Index	Ln(Var.)	6.70	4.83	6.00
	ADF Result	> 0.10	> 0.10	> 0.10
1M-Diff	**Ln(Var.)**	**-0.67**	**-1.59**	**-0.45**
	ADF Result	**< 0.05**	**< 0.05**	> 0.10
1Q-Diff	Ln(Var.)	**1.10**	**-0.07**	**1.41**
	ADF Result	> 0.10	**< 0.01**	> 0.10
1Y-Diff	Ln(Var.)	**3.39**	**1.34**	**3.75**
	ADF Result	> 0.10	> 0.10	> 0.10
M/M	**Ln(Var.)**	**-6.84**	**-7.52**	**-6.64**
	ADF Result	**< 0.05**	**< 0.05**	> 0.10
Q/Q	Ln(Var.)	**-7.29**	**-8.19**	**-6.96**
	ADF Result	> 0.10	**< 0.01**	> 0.10
Y/Y	Ln(Var.)	**-7.86**	**-9.52**	**-7.41**
	ADF Result	> 0.10	> 0.10	> 0.10
1Y-Diff, 1Q-Diff	**Ln(Var.)**	**1.47**	**0.63**	**2.22**
	ADF Result	**< 0.05**	**< 0.01**	> 0.10
Y/Y, 1-Diff	**Ln(Var.)**	**-11.20**	**-11.69**	**-10.71**
	ADF Result	**< 0.01**	**< 0.05**	> 0.10

We take transforms for which we have significant evidence of a unit-root with inflation as shown in the previous table and apply them to our independent variables to determine where stationarity is established simultaneously. The process by which a transform is selected for further analysis is described in the previous section. Selected processes are bolded in the following table.

Table 4.1: Independent Variable Stationarity

DAILY, WEEKLY & MONTHLY VARIABLES	Value		1M-Diff			M/M			Y/Y, 1M-Diff		
	ln(Var.)	ADF-Stat	ln(Var.)	ADF-Stat		ln(Var.)	ADF-Stat		ln(Var.)	ADF-Stat	
Gasoline, Regular	-2.76	-2.29	**-5.41**	**-6.34**	***	-0.14	†		4.09	†	
Lumber Price Index	8.13	-1.81	**5.73**	**-7.15**	***	0.16	-4.11	***	4.58	-6.21	***
Median Price Per Square Foot	4.22	-0.57	**-0.44**	**-4.85**	***	-3.71	-4.74	***	0.16	-2.99	
Median Days on Market	5.15	-3.16	**3.73**	**-5.62**	***	1.1	-4.66	***	4.2	-4.19	***
Active Listings	25.28	-1.18	**21.52**	**-5.5**	***	1.36	-3.69	**	3.57	-3.03	
Rent of Primary Residence	7.89	-1.97	-0.94	-2.54		-7.9	-2.5		**-3.49**	**-2.98**	
Water Freight Index	5.94	-1.22	**1.62**	**-4.75**	***	-2.85	-4.68	***	1.58	-4.02	***
Truck Freight Index	5.84	-2.43	0.53	-3.3	*	**-4.32**	**-3.3**	*	0.6	-3.27	*
Global Supply Chain Pressure Index	0.35	-2.31	**-1.83**	**-6.38**	***	78.26	†		15.37	†	
Total Inventories	21.81	-2.92	16.32	-3.85	**	-5.79	-3.81	**	**-0.48**	**-4.2**	***
Total Inventory to Sales Ratio	-5.42	-2.12	**-7.13**	**-6.52**	***	-2	†		-6.37	-6.34	***
Producer Price Index less Fuel	6.48	-1.74	**0.14**	**-3.17**	*	-5.57	-3.13		-0.84	-2.93	
Real Personal Income	15.27	-2.64	**12.24**	**-7.82**	***	-0.81	-5.54	***	2.64	†	
Total Unemployment	16.23	-2.93	**14.3**	**-6.92**	***	22.75	†		6.27	-6.51	***
Labor Leverage Ratio	-1.03	-2.15	-3.13	-6.96	***	32.77	†		**-2.3**	**-7.1**	***
Inflation Expectation, Derived from Bonds	-0.84	-3.86	**-1.7**	**-8.3**	***	30.06	†		-1.15	-7.29	***

† Because variance was not reduced by the transform, an ADF test was not applied

Table 4.2: Independent Variable Stationarity (continued)

DAILY, WEEKLY & MONTHLY VARIABLES	Value		1M-Diff			M/M			Y/Y, 1M-Diff		
	ln(Var.)	ADF-Stat	ln(Var.)	ADF-Stat		ln(Var.)	ADF-Stat		ln(Var.)	ADF-Stat	
Inflation Expectation, Consumer Survey	-0.57	-1.67	**-2.28**	**-5.38**	***	5.05	†		-1.84	-5.08	***
Real Personal Expenditure	14.63	-2.56	**10.28**	**-7.12**	***	-3.61	-6.23	***	1.46	-7.05	***
Federal Funds Rate	1.1	-2.95	#			#			**-3.32**	**-2.3**	‡
M2 Money Supply	14.11	-1.9	7.94	-3.4	*	**-4.03**	**-4.01**	**	0.37	-3.95	**

† Because variance was not reduced by the transform, an ADF test was not applied

‡ This variable is included in analysis despite being non-stationary due to its analytical importance

Since the Federal Funds rate is reported as annual percent, we assume that it is already in the Y/Y form

Table 5: Independent Variable Stationarity, Quarterly

QUARTERLY VARIABLES	Value		1Q-Diff			1Y-Diff, 1Q-Diff		
	ln(Var.)	ADF-Stat	ln(Var.)	ADF-Stat		ln(Var.)	ADF-Stat	
Renter Occupied Housing	15.46	-2.36	-6.05	-4.16	***	**13.24**	**-7.26**	***
Corporate Profits	9.67	-2.32	-2.06	-3.72	**	**8.75**	**-5.42**	***
Employment Cost Index	5.71	-0.89	-8.76	-2.55		**-2.03**	**-3.93**	**
Government Transfers to Persons	10.78	-2.47	**1.45**	**-2.69**		11.47	†	
Velocity of Money	-3.53	-1.89	-4.79	-2.9		**-5.88**	**-5.02**	***

† Because variance was not reduced by the transform, an ADF test was not applied

4.2 Rolling-Window Granger Causality Model

The following table lists which variables we found evidence of a Granger causal relationship with inflation and over what interval.

Table 6: Granger Significant Intervals

INDEPENDENT VARIABLE	START	END
Gasoline	2019-02-01	2019-04-01
Real Personal Expenditure	2020-04-01	2020-06-01
Labor Leverage Ratio	2020-06-01	2020-10-01
	2021-04-01	2021-10-01
Water Freight	2022-06-01	2023-06-01
Federal Funds Rate	2023-03-01	2023-07-01

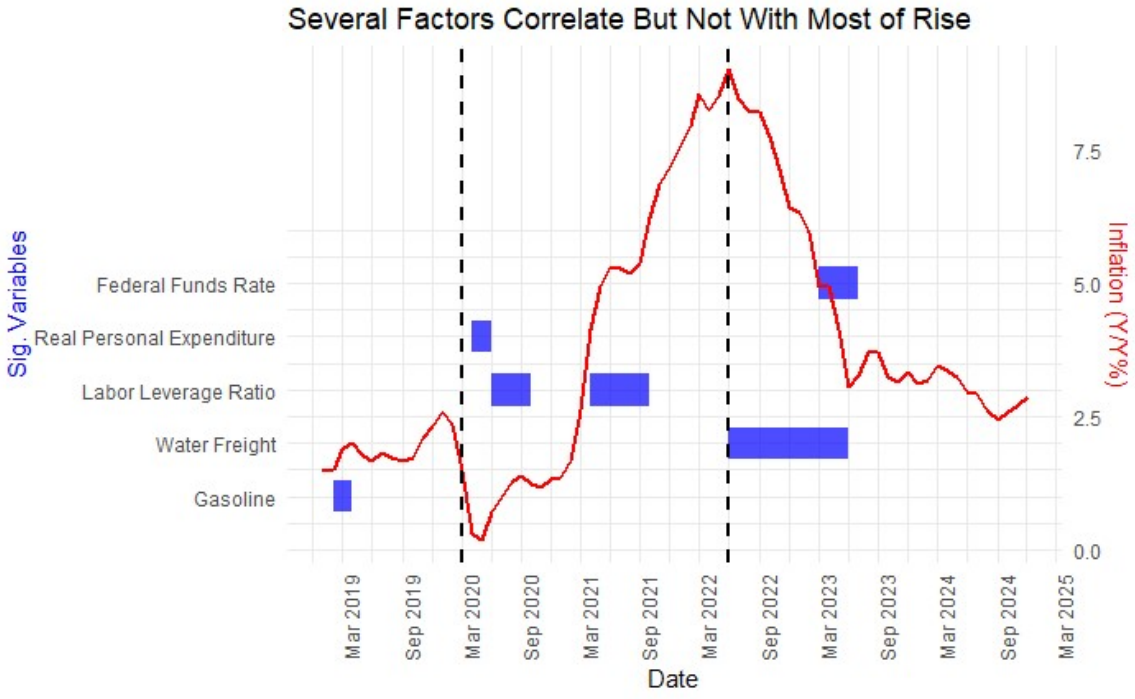

Figure 4: Timeline of Granger Causality Superimposed on Inflation

4.3 Time-Interaction Linear Model

The table below shows the coefficients and significance levels for the time-interaction linear models. As stated in the Methodology section, we fit the linear model for CPI inflation for each event in the list of events and only fit the models for the independent variables where an event corresponded to a period that we had significant evidence of Granger causality. Despite finding five variables that met our criteria for significance, only the Water Freight Index had an interval that overlapped an event that could be relevant to it. The coefficients for the interaction terms in the two linear trend models in shown below.

Table 7: Time-Interaction Linear Model Result

		Consumer Price Index		**Water Freight Index**	
Event	**Date**	Interact.	Sig.	Interact.	Sig.
Inflation Reduction Act	2022/08/16	**-2.46E-03**	***	**-7.26E-03**	*

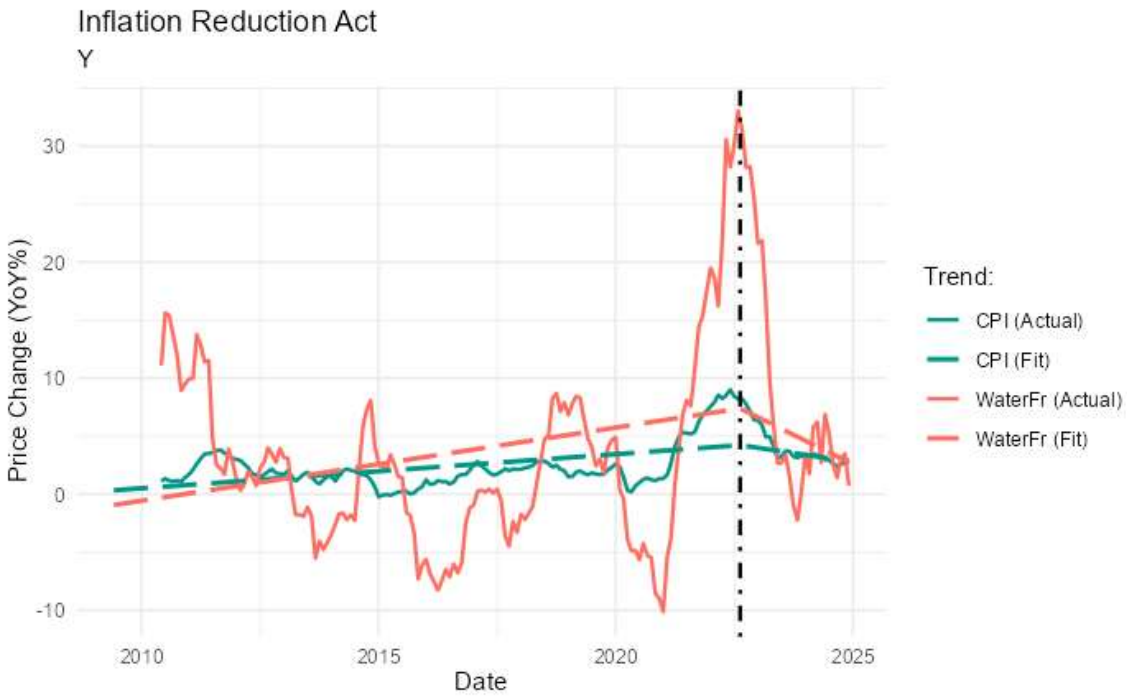

Figure 5: Time-Interaction Linear Model Result

5. CONCLUSION

5.1 What Can We Say

From the evidence we have collected, we can see that Granger Causality for Real Personal Expenditures and the Labor Leverage Ratio correspond with the period immediately following stay-at-home orders, the period of greatest acceleration in inflation coincided with evidence of Granger causality with LLR, and inflation reaching its peak and decelerating correlate with Granger Causality for the Federal Funds Rate and the Water Freight Index.

This would imply that the initial drop in prices was caused by a fall in consumer spending. Moreover, this provides evidence that the deceleration in inflation was likely caused by falling shipping costs, and the Federal Reserve's shift to an active monetary policy at best played a secondary role in mitigating price increases. The linear trend model seems to suggest that this shift to disinflation correlates with the passage of the Inflation Reduction Act; however, more research is needed before attributive claims can be made.

5.2 Limitations

This analysis was based on several assumptions and therefore has several limitations. Perhaps the most immediate is choice of variables and transformations. That we were unable to attribute the full inflationary surge to a handful of variables in our analysis provides a strong argument that we have not identified the proper explanatory variables. On the other hand, it could be the case that we chose to fit the Granger models on the incorrect transformation of the data. The choice of variables and transforms, including the choice not to apply percent-change to measurements that were already percentages or ratios, was informed by the author's experience conducting similar analyses in industry.

For at least one variable, the choice between M/M and Y/Y, 1M-Diff produced differing results and interpretations from our implementation of the Rolling-Window Granger Causality

model. As previously discussed, we chose the transform with the lowest p-value provided that the transform produced a lower variance, and when two or more transforms generated p-values lower than 0.01, we chose the one with the lowest variance.

This analysis was conducted without the explicit use of the Bonferroni correction. While we chose a significance level of 0.01 to adjust for multiple comparison concerns, we are limited by the Augmented Dickey-Fuller test in the "tseries" R package, which rounds sufficiently small p-values up to 0.01. The power of our methodology could be calculated directly or estimated using Monte Carlo.

The choice to use a time-interaction linear model and to fit it over the annual percent change, or equivalent, is not an obvious one. This approach was appealing due to the smoothness of the data and the ease of interpretation of the results. As mentioned previously, this model cannot give us evidence in favor of a causal link between an event and a change in trend in the data; however, the lack of evidence of a correlation between the two would provide an argument against the presence of such a link.

The fact that so few of the events we identified coincided with periods that we found significant evidence of Granger causality speaks to the drawbacks in this approach. One potential alternative approach could be to fit linear spline models over each of the variables, identify which have coinciding knots, and consult news archives for potential explanations.

Finally, while the Labor Leverage Ratio was identified as being one of the variables that was significant over the longest term, we cannot speak to the robustness of this measurement. It is a frequent practice for employers to incentive resignations or separations in such a way as to minimize the number of layoffs or firings that are done. Since the LLR is computed as the ratio of quits to layoffs in a given period, if not properly accounted for, such incentive structures would highly skew the quotient. Additional research into how the Bureau of Labor Statistics conducts

the Job Openings and Labor Turnover Survey is needed before conclusions can be made from this measure.

5.3 Future Analysis

In addition to re-examining the assumptions and limitations described above, a follow-up analysis would benefit greatly from testing the robust of these results. This analysis could be repeated for the CPI Special Aggregate, All Items less Food and Energy, and the Personal Consumption Expenditure Survey All Items and All Items less Food and Energy Price Indices. If the results of this analysis are replicated with these indicators, then it would be a strong argument for the robustness of this methodology.

Appendix A

The following are the Rolling-Window Granger Causality plots for each independent variable. It is worth noting that the p-values have been rescaled using the absolute value of a logarithmic transform. As such, higher values in these plots imply stronger evidence. The horizontal lines show the log-transforms of 0.01, 0.05 and 0.10 from top to bottom. The vertical lines show the dates for initial stay-at-home orders and peak inflation.

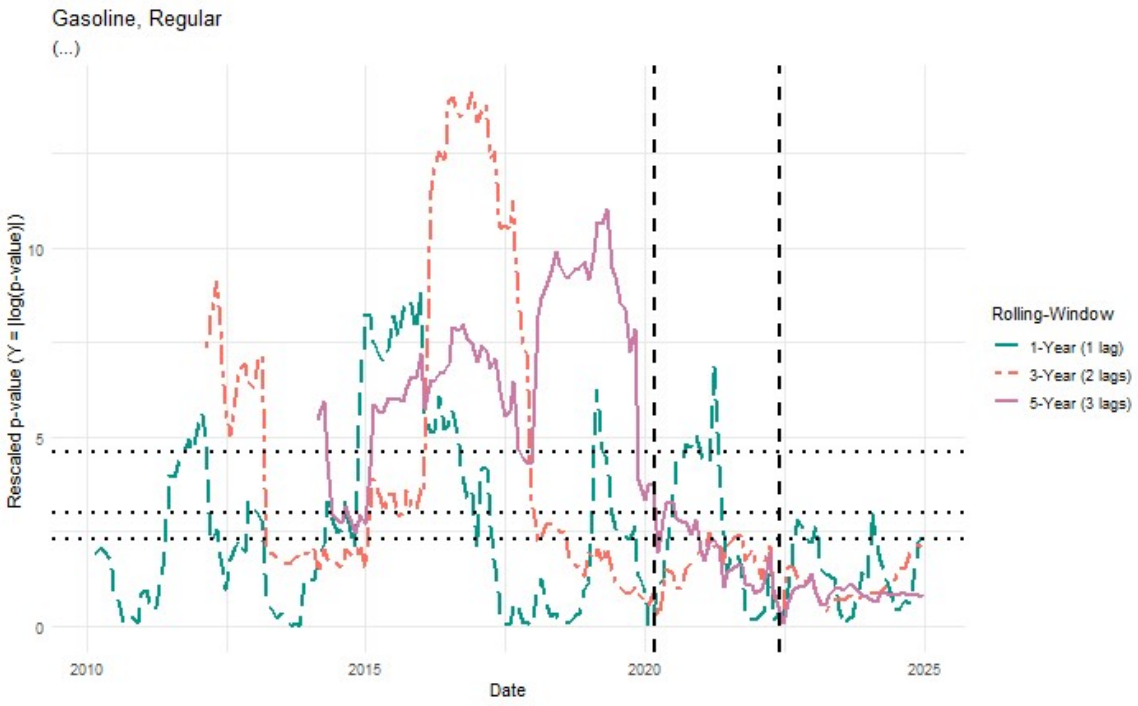

Figure A.1: Granger Causality, Gasoline

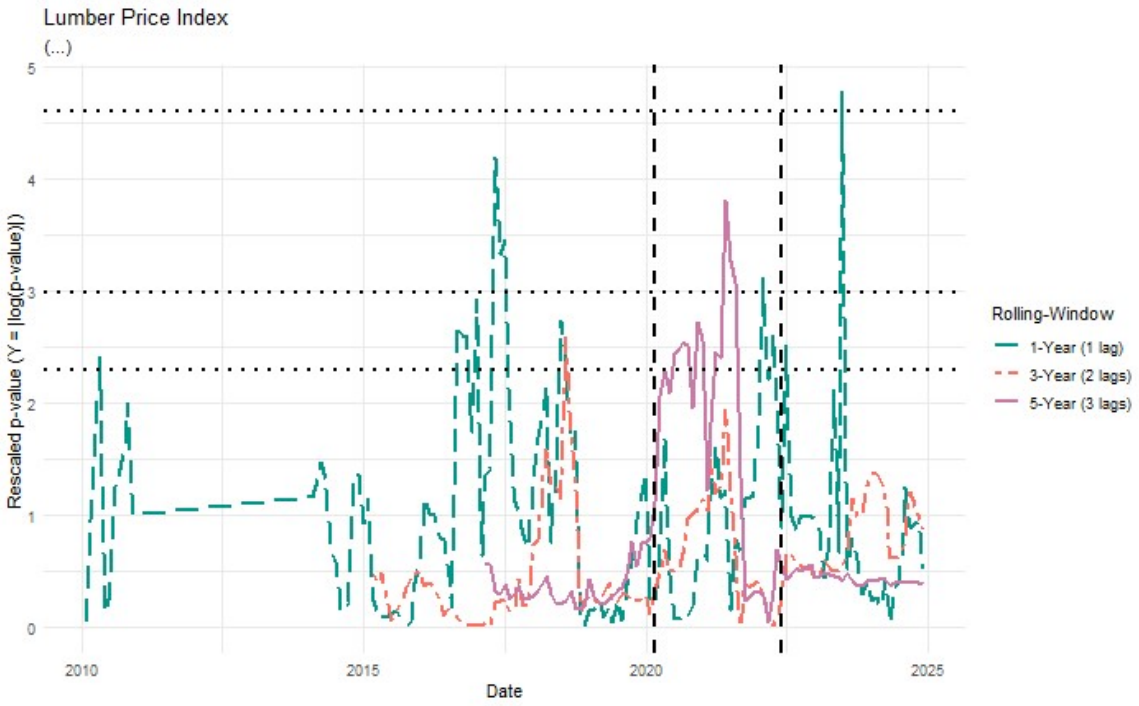

Figure A.2: Granger Causality, Lumber Price Index

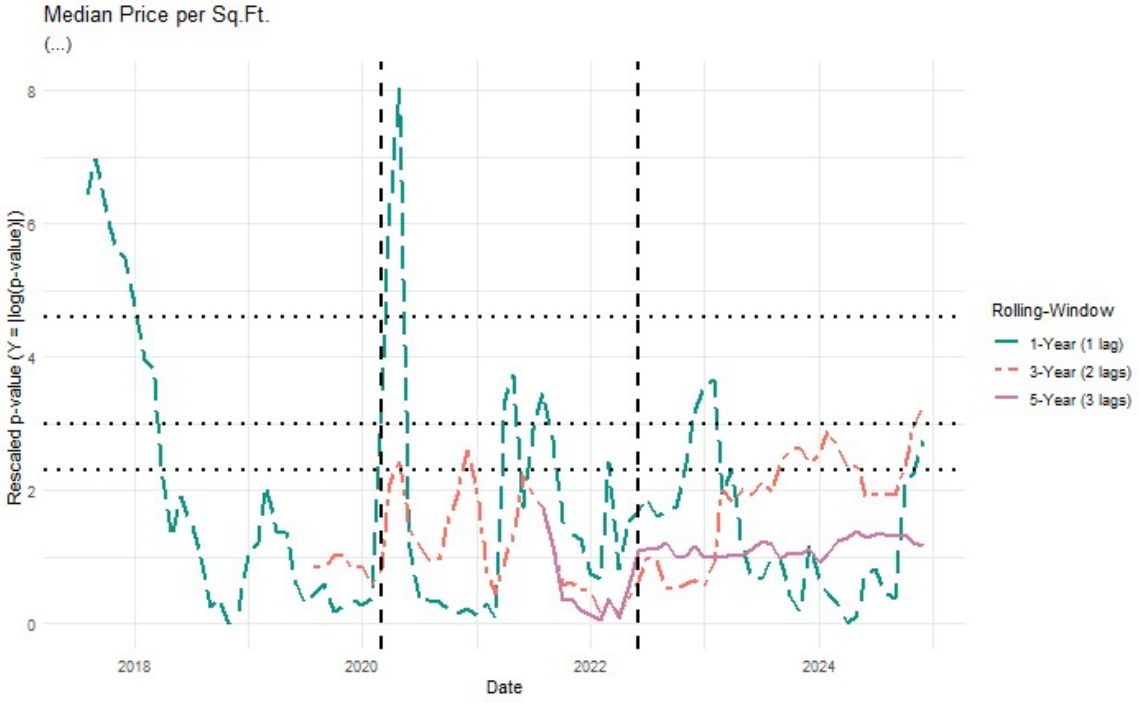

Figure A.3: Granger Causality, Median Price per Square Foot

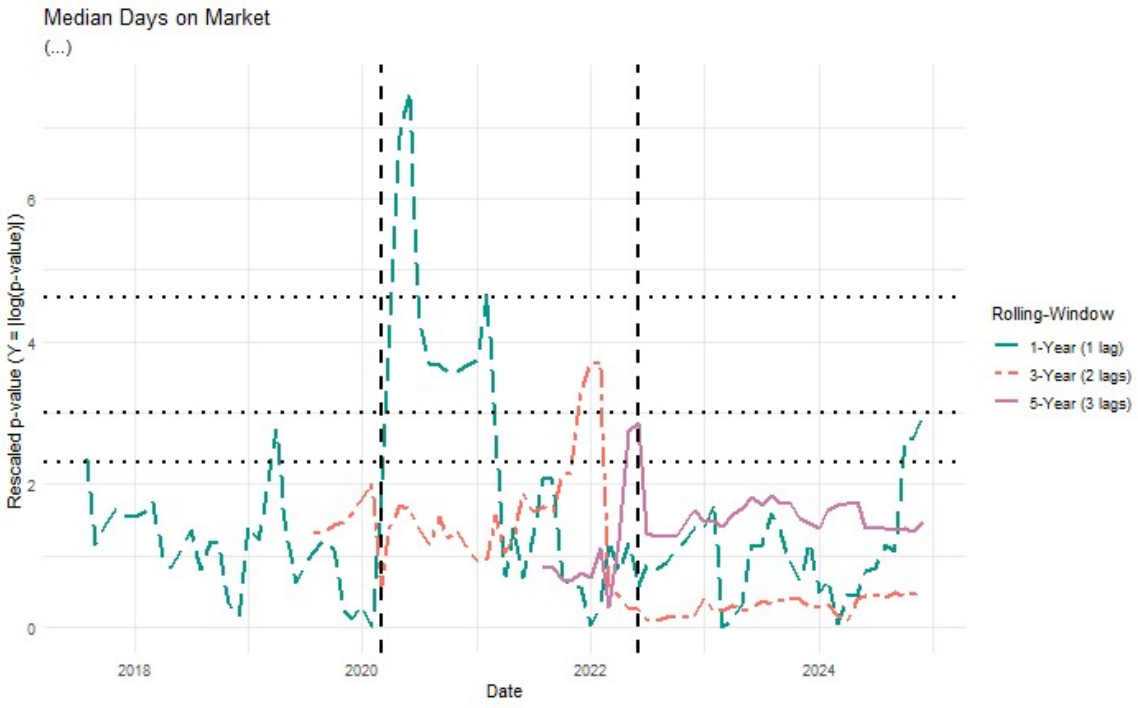

Figure A.4: Granger Causality, Median Days on Market

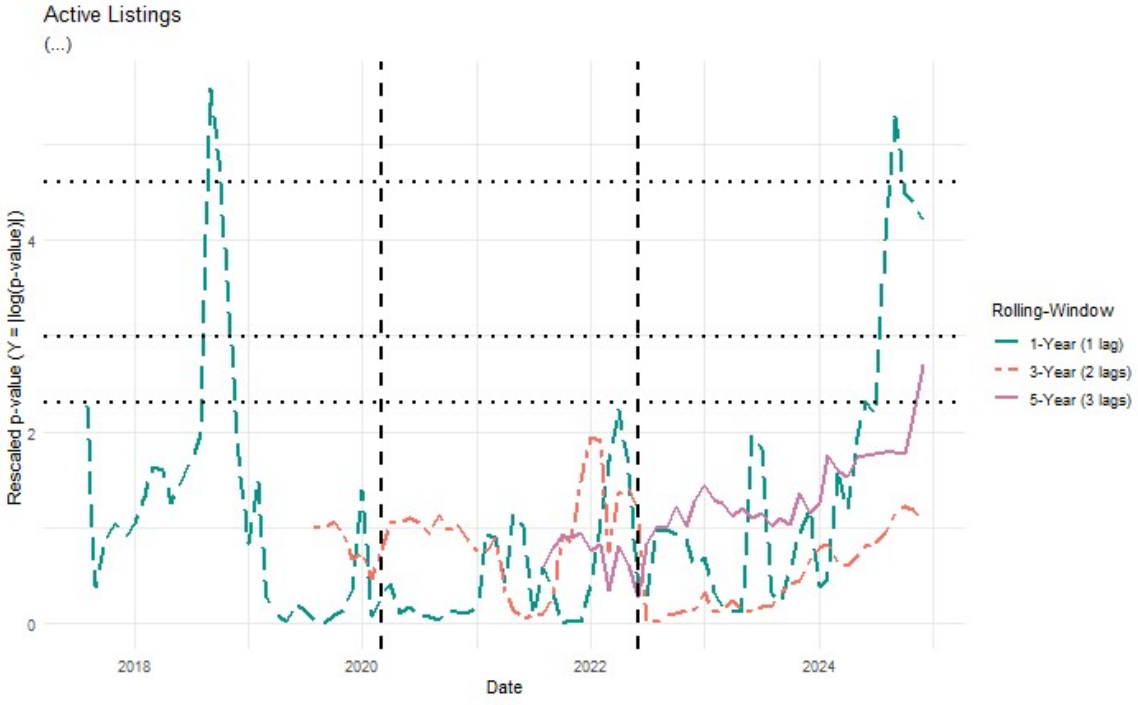

Figure A.5: Granger Causality, Active Listings

Figure A.6: Granger Causality, Renter Occupied Housing

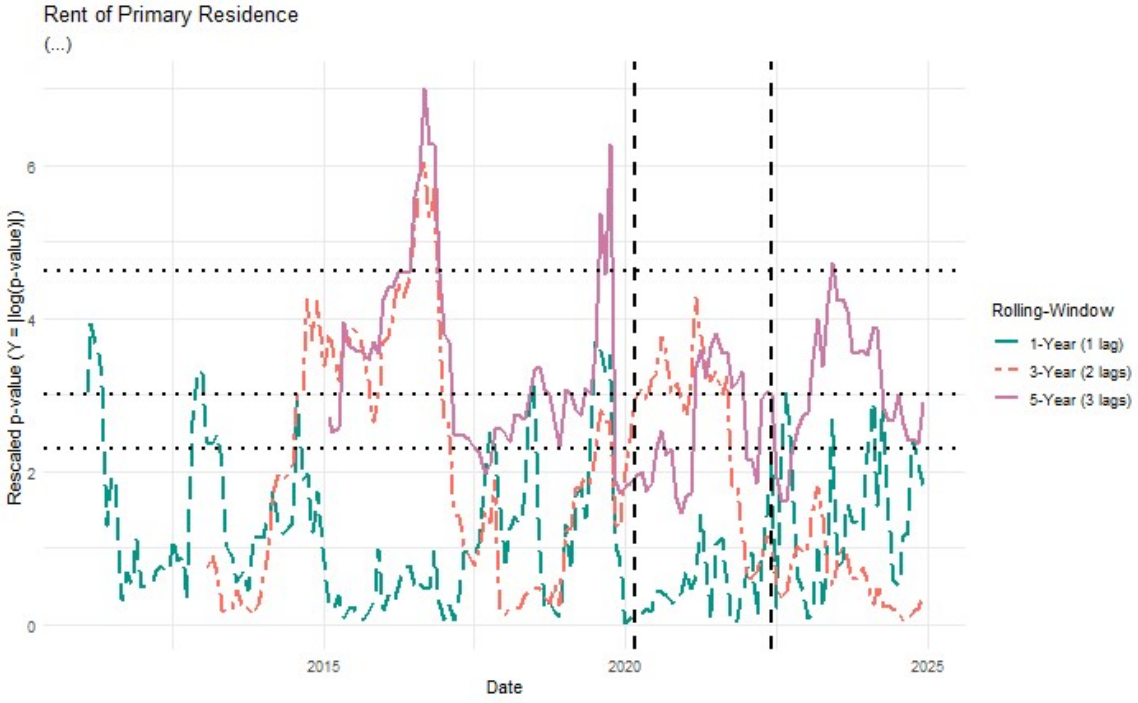

Figure A.7: Granger Causality, Rent of Primary Residence

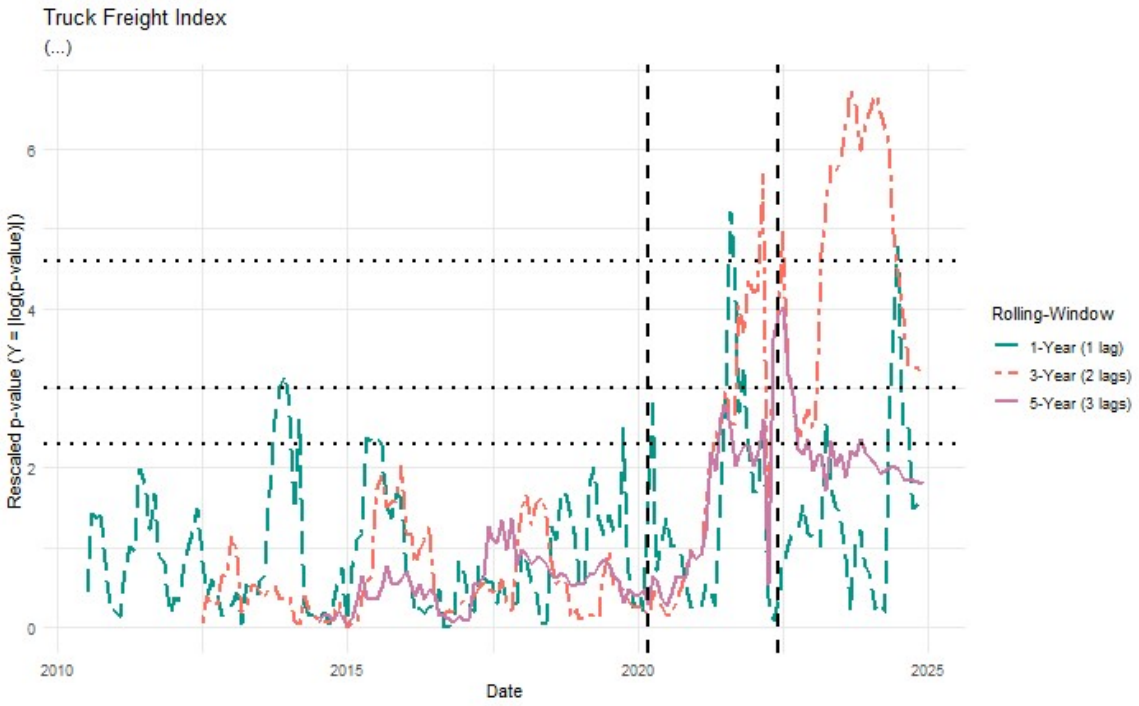

Figure A.8: Granger Causality, Truck Freight Index

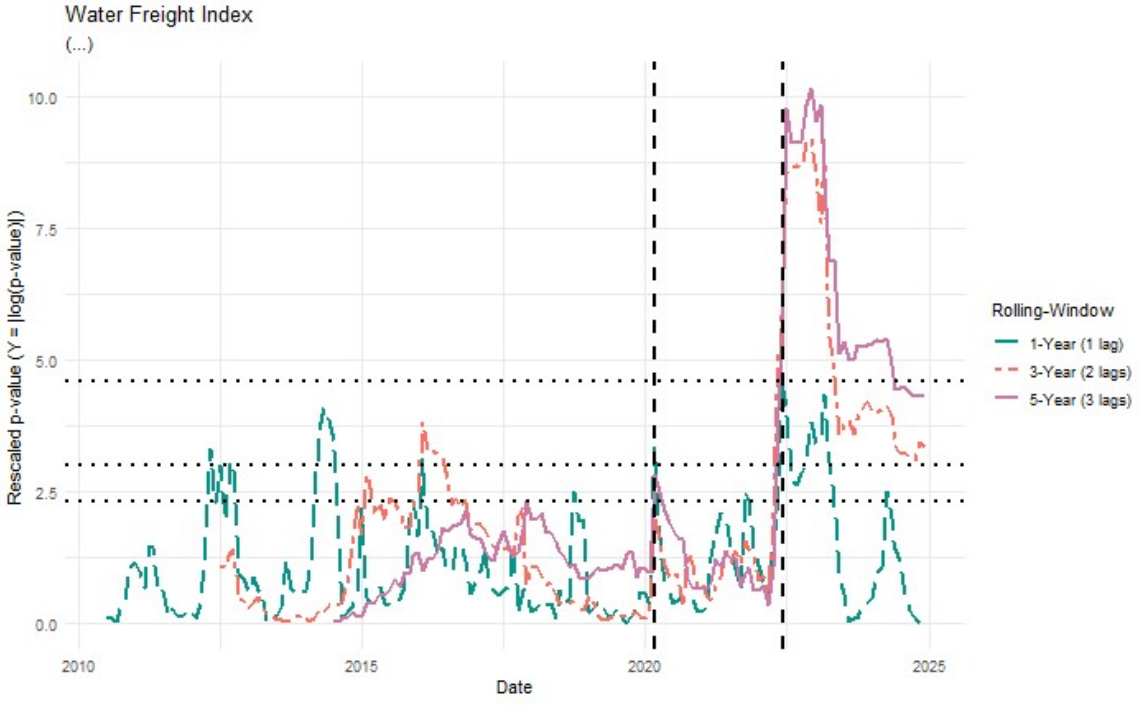

Figure A.9: Granger Causality, Water Freight Index

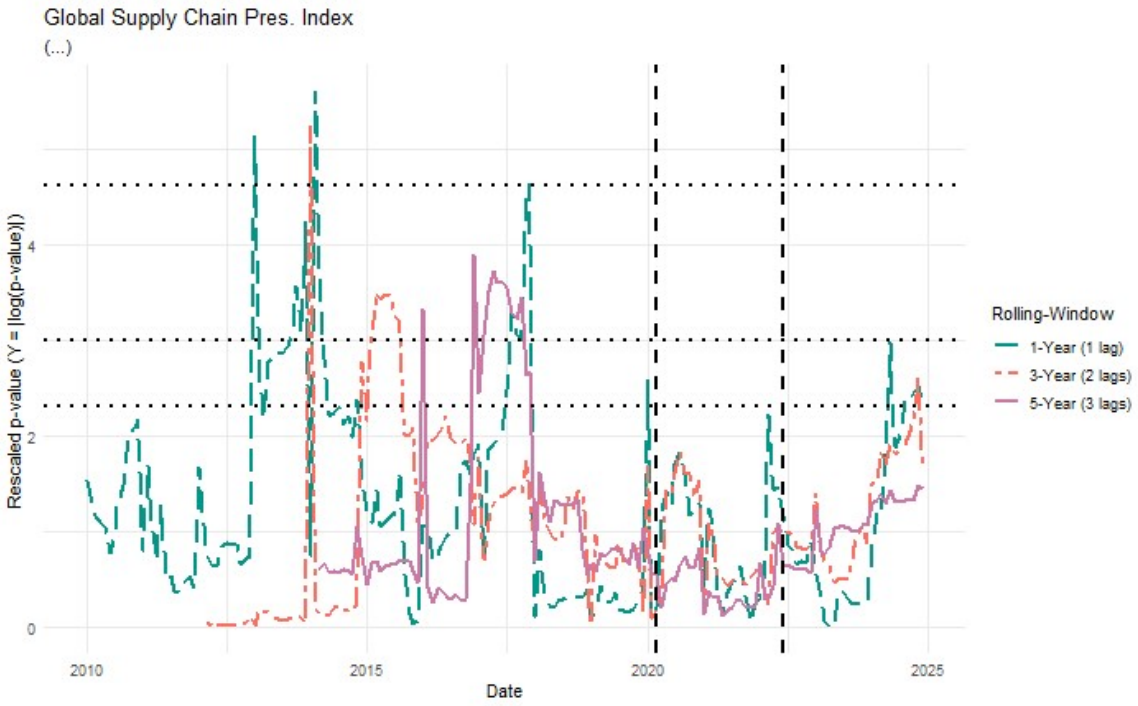

Figure A.10: Granger Causality, Global Supply Chain Pressure Index

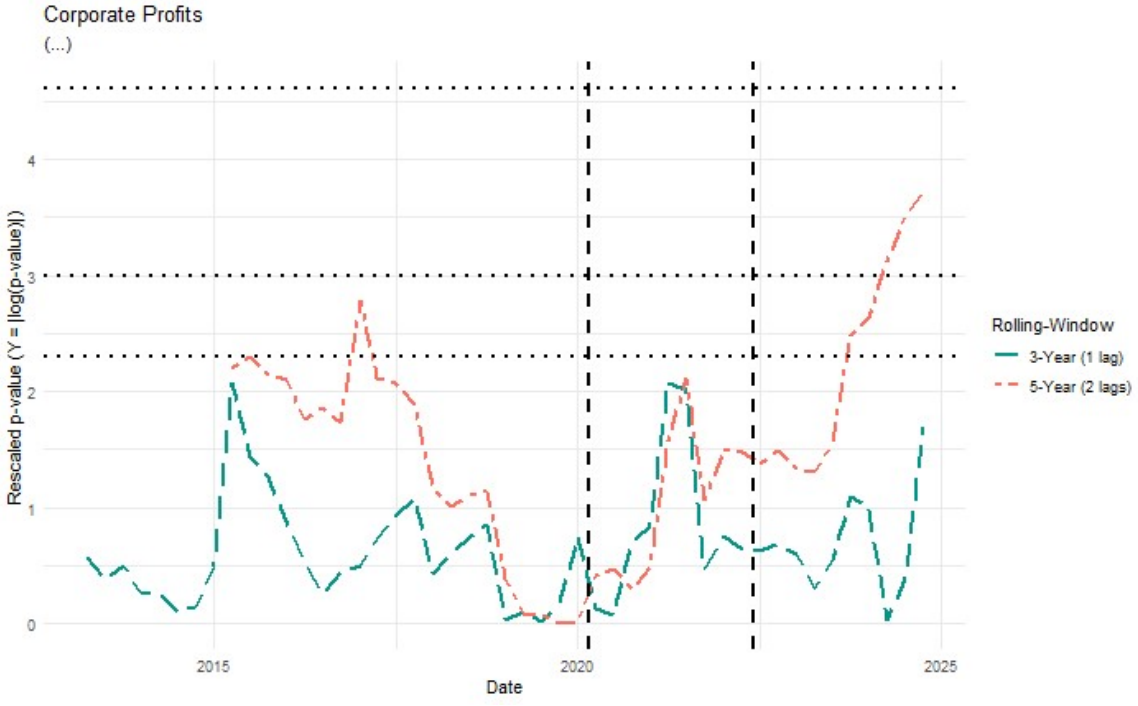

Figure A.11: Granger Causality, Corporate Profits

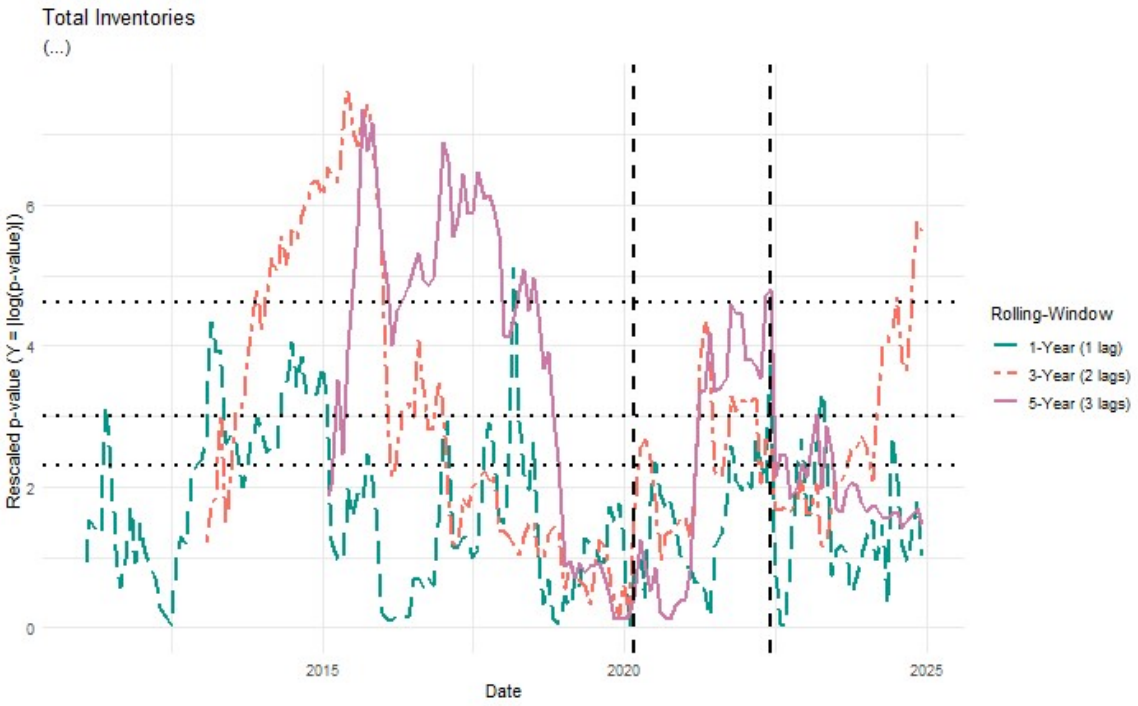

Figure A.12: Granger Causality, Total Inventories

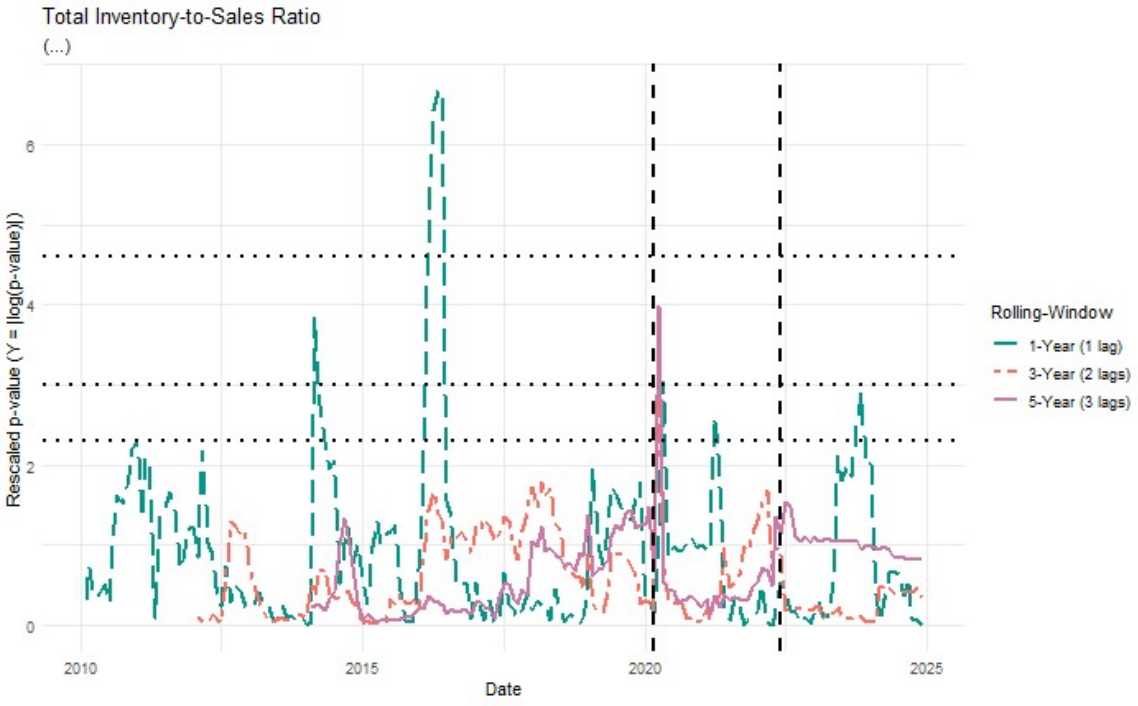

Figure A.13: Granger Causality, Total Inventory-to-Sales Ratio

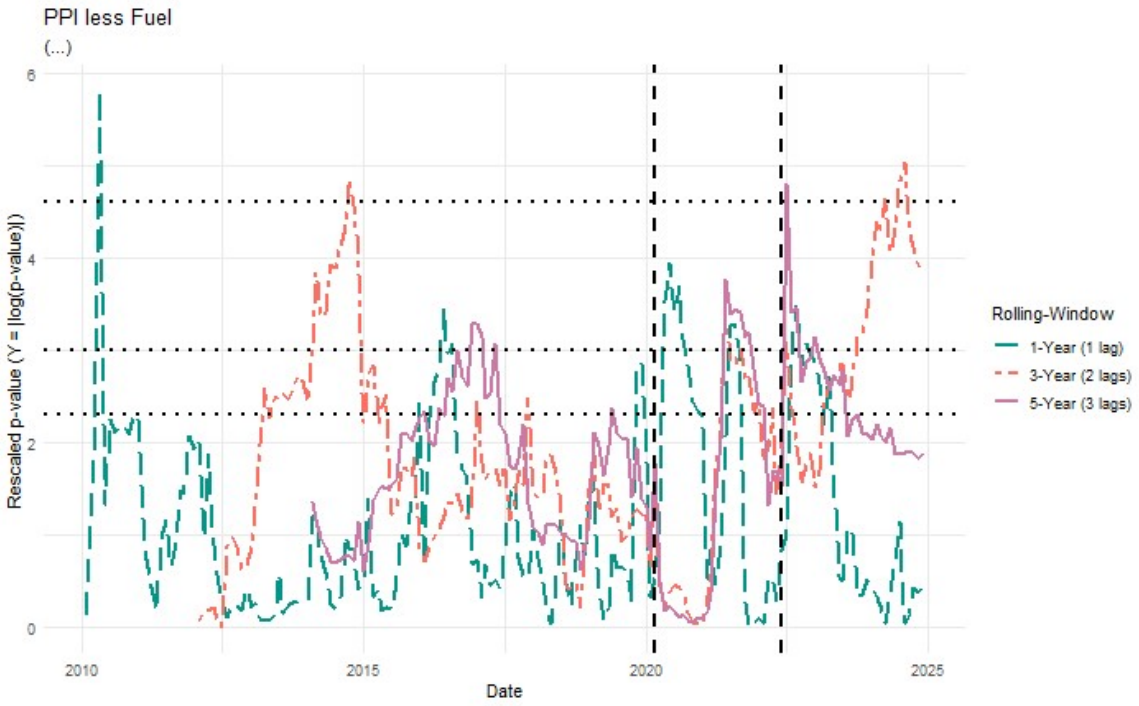

Figure A.146: Granger Causality, Producer Price Index less Fuel

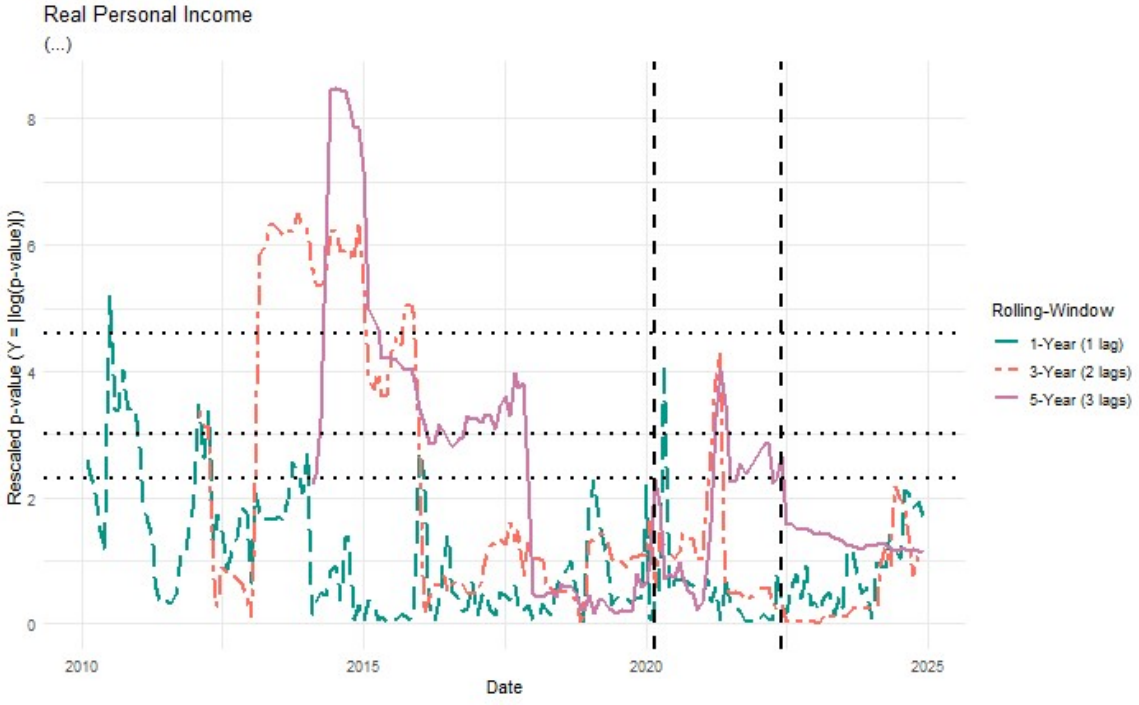

Figure A.15: Granger Causality, Real Personal Income

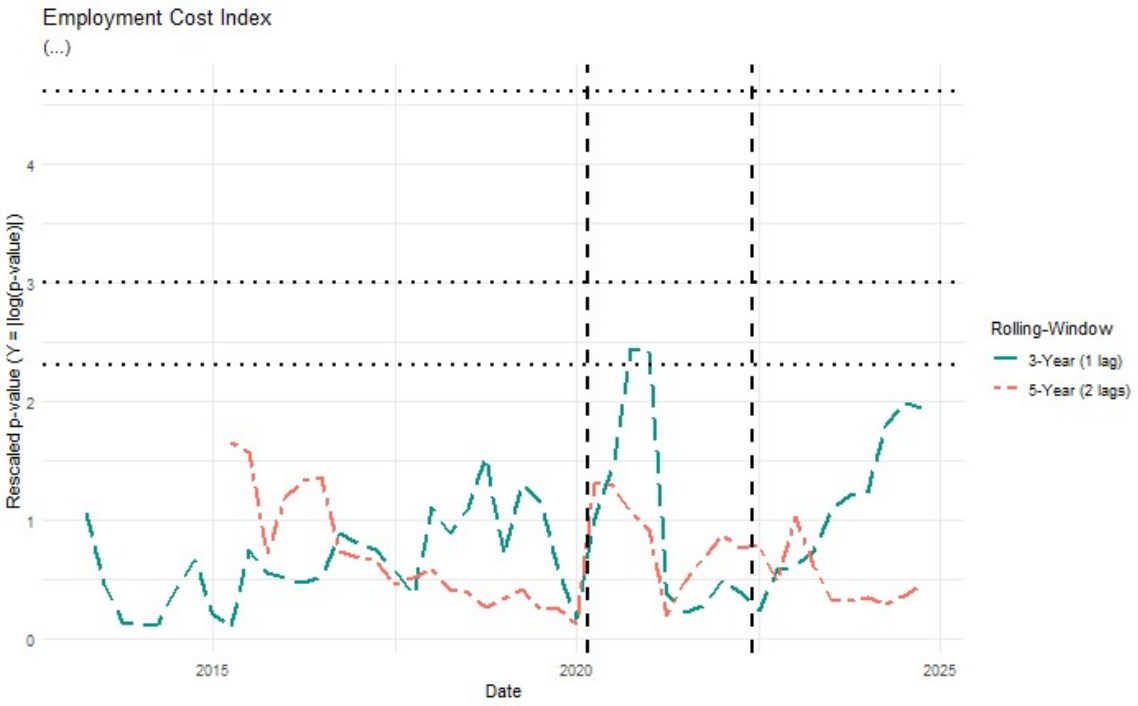

Figure A.16: Granger Causality, Employment Cost Index

Figure A.177: Granger Causality, Labor Leverage Ratio

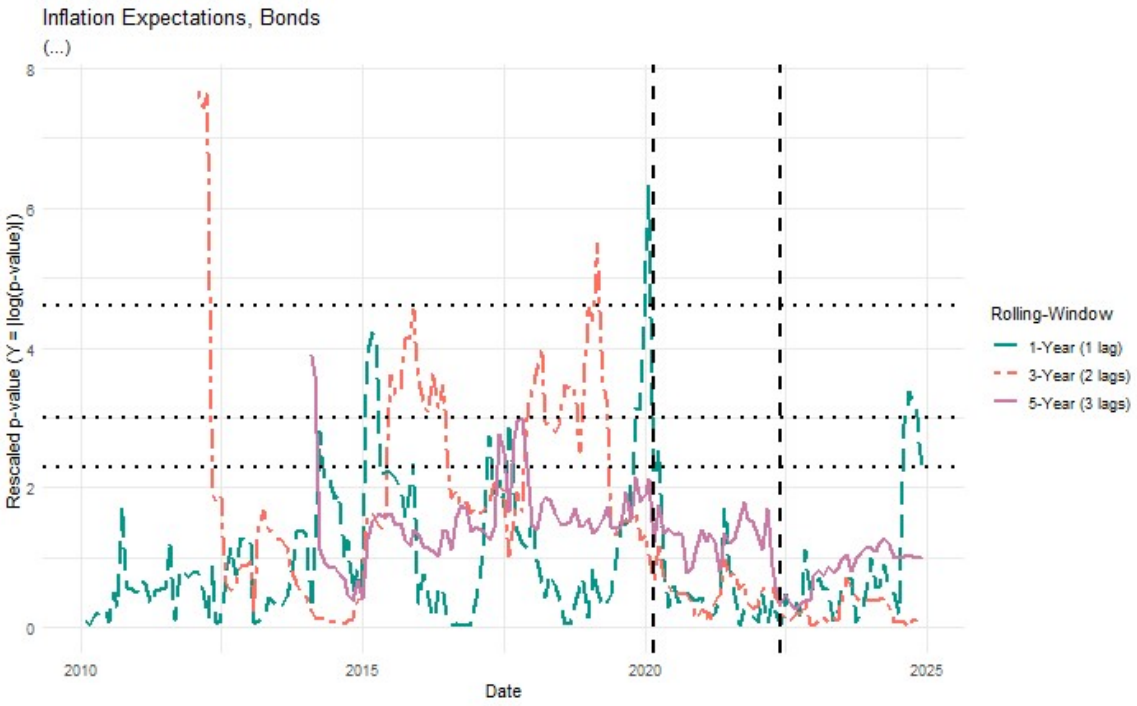

Figure A.188: Granger Causality, Inflation Expectations Derived from Bonds

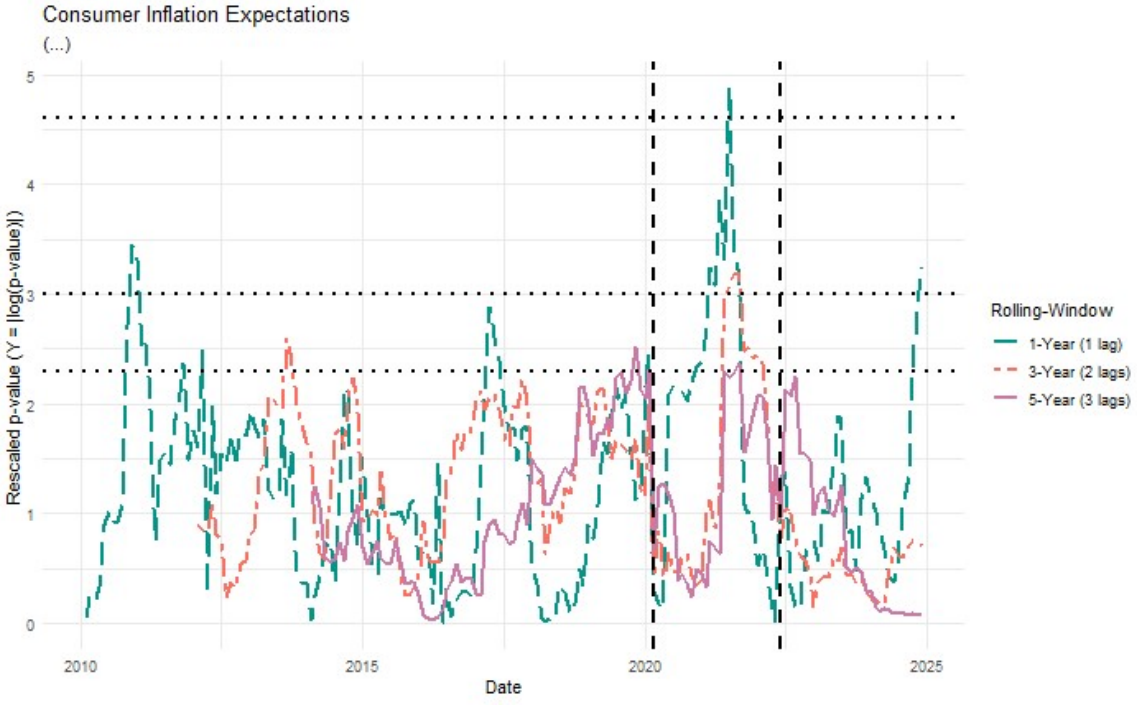

Figure A.199: Granger Causality, Consumer Inflation Expectations

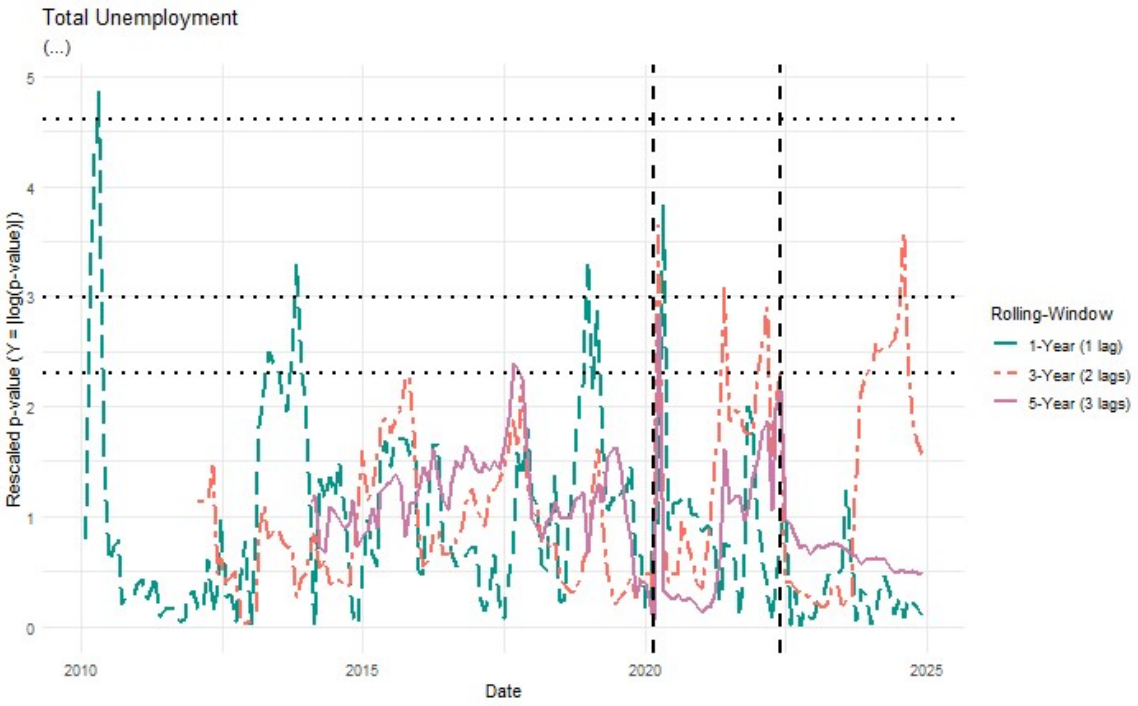

Figure A.2010: Granger Causality, Total Unemployment

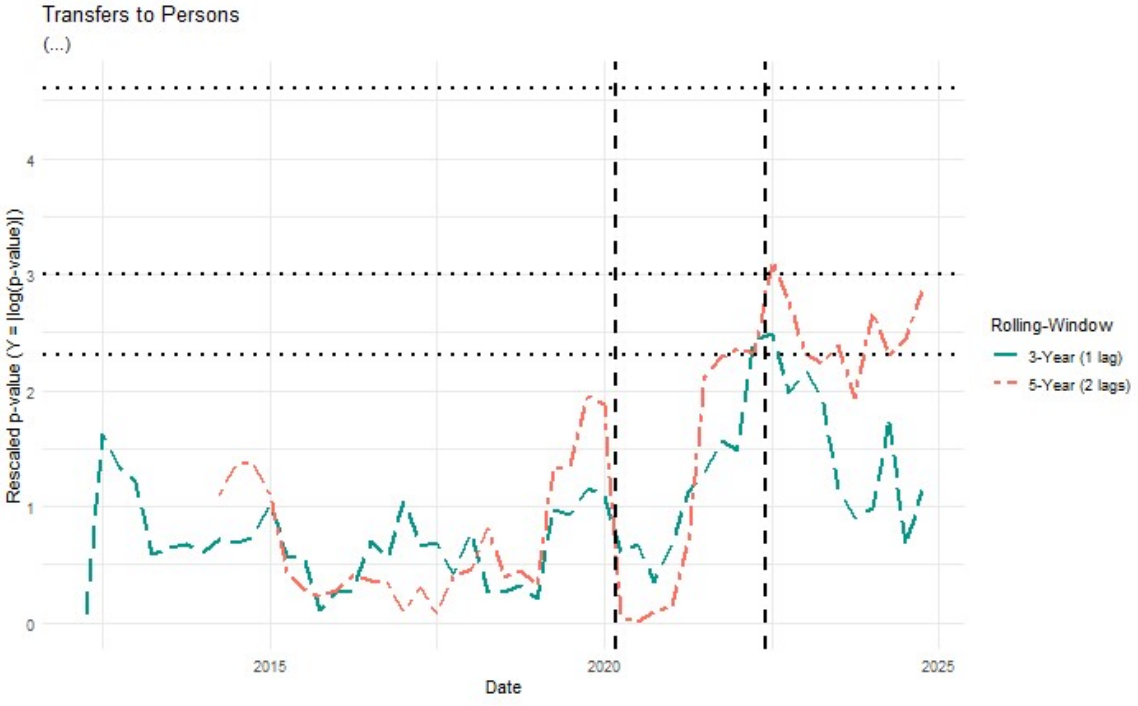

Figure A.2111: Granger Causality, Transfers to Persons

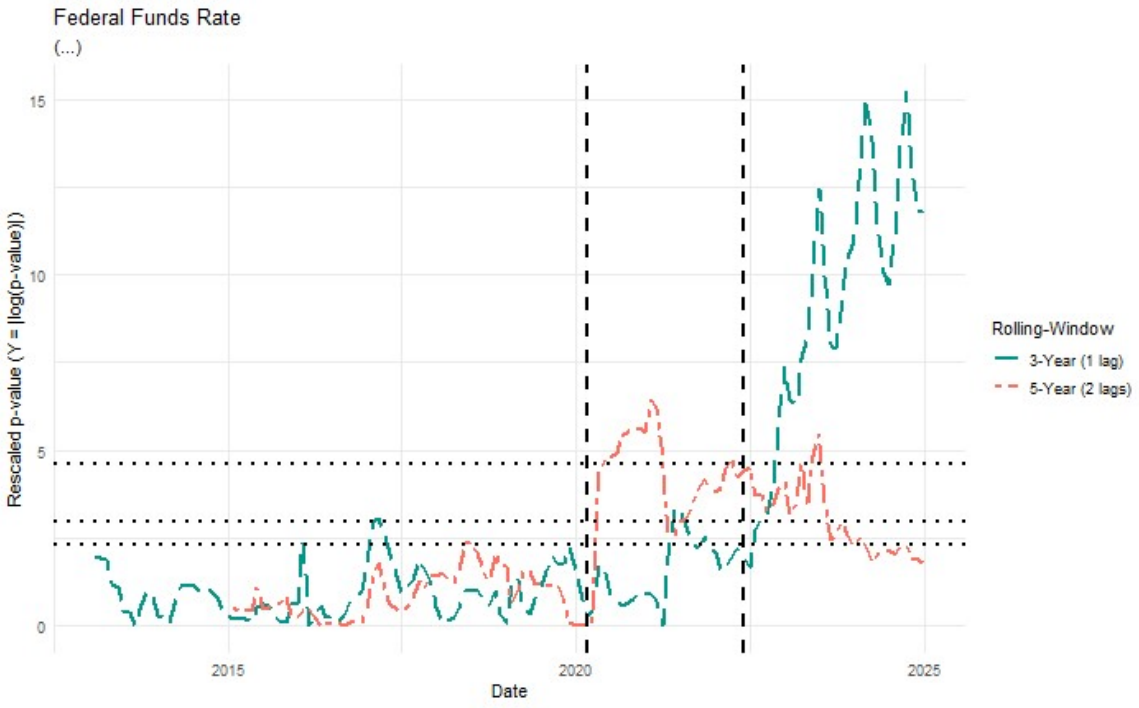

Figure A.2212: Granger Causality, Federal Funds Rate

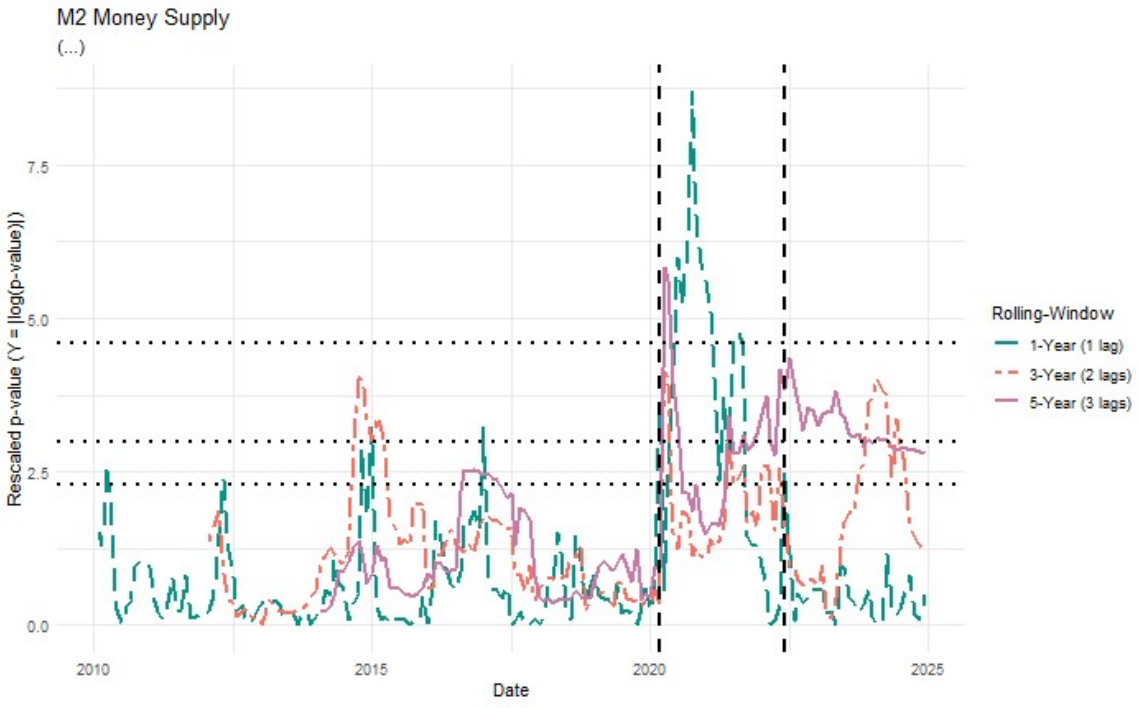

Figure A.2313: Granger Causality, M2 Money Supply

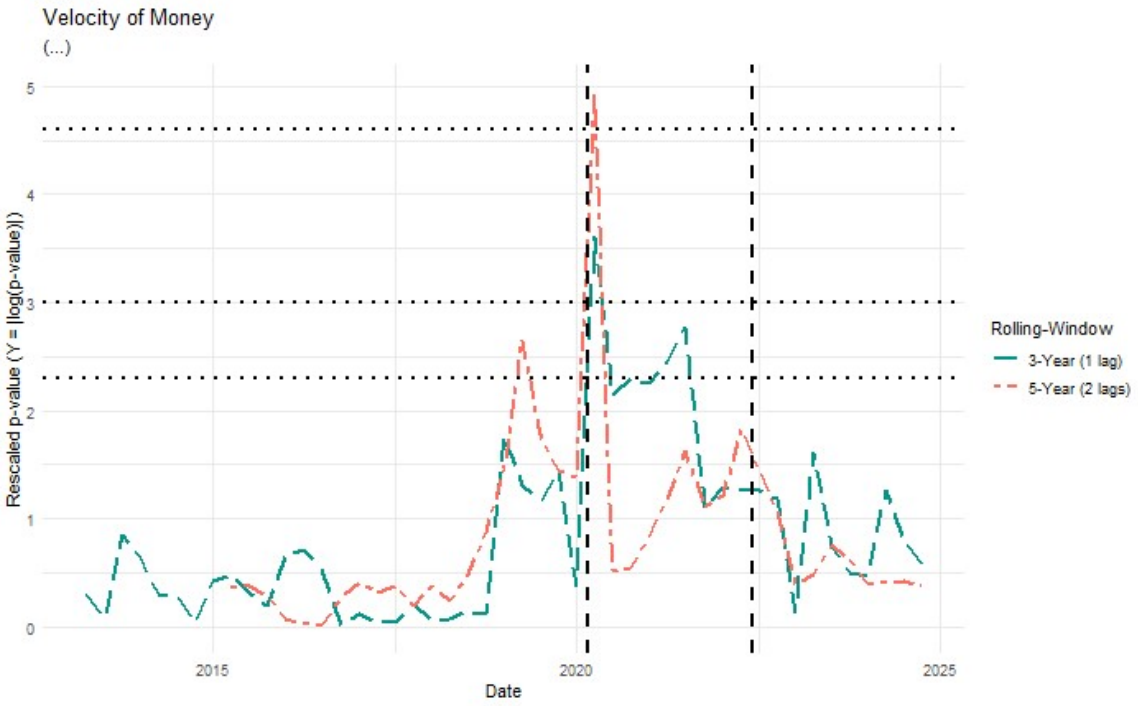

Figure A.2414: Granger Causality, Velocity of Money

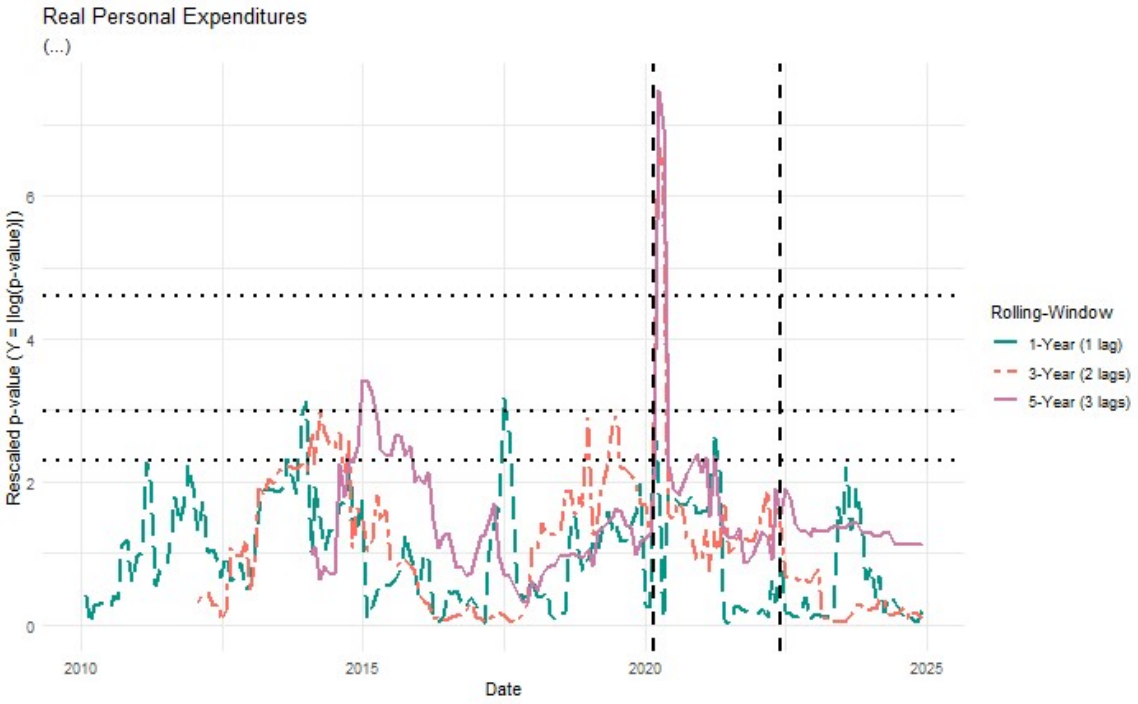

Figure A.2515: Granger Causality, Real Personal Expenditure

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