Macroeconomic Influences on Healthcare Expenditures

A Comprehensive Econometric Approach with Markov Switching and Non-Linear Terms

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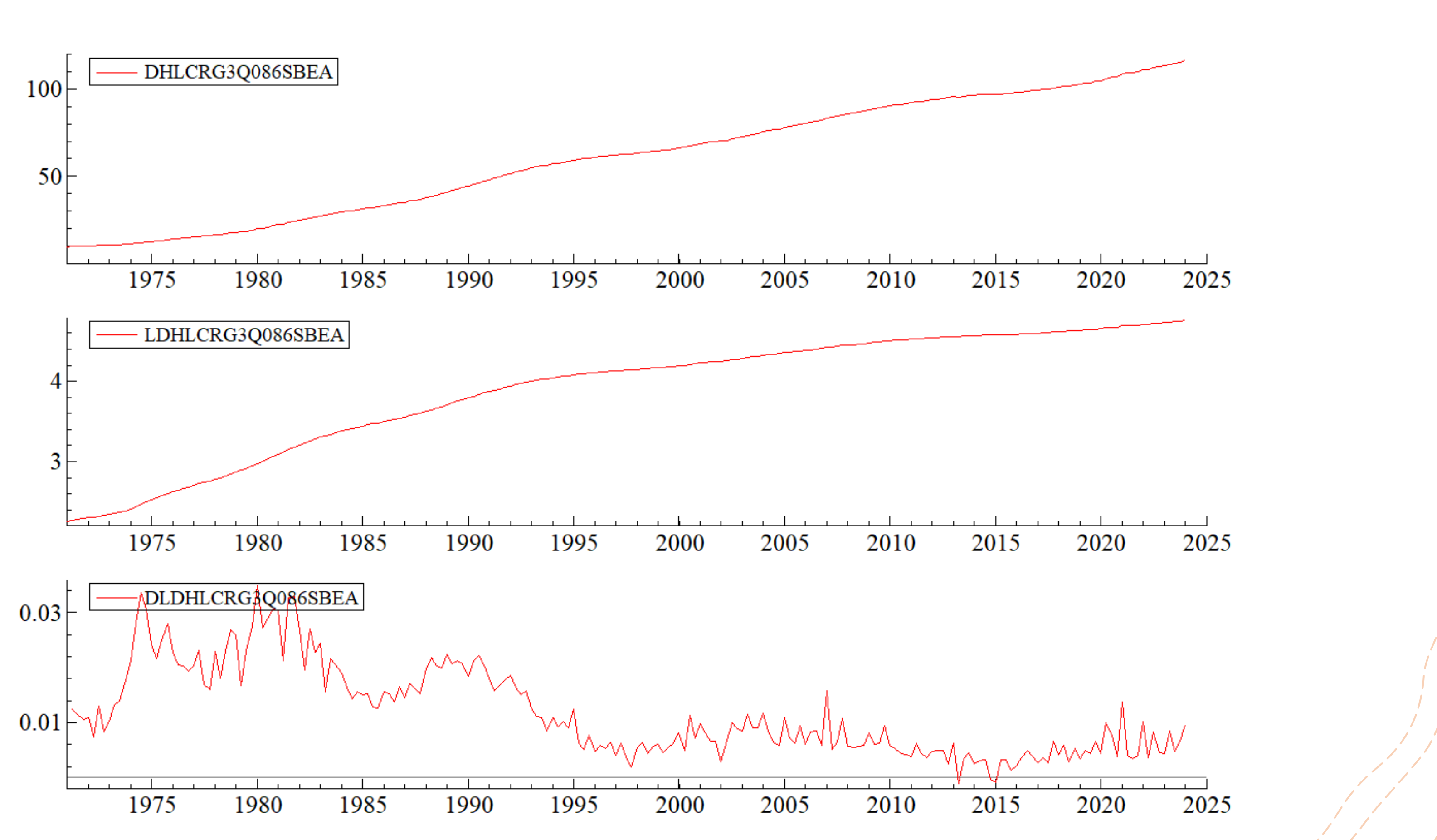
Overview

The goal of this project is to understand the economic drivers of Personal Consumption Expenditures on Health Care (PCE-Health).

This dependent variable represents the expenditure on healthcare services within the broader economic context, providing insights into factors that affect healthcare spending.

Personal Consumption Expenditures on Health Care (PCE-Health)



Independent Variables

- **Time Period**: 1971-01-01 to 2024-01-01
- **Frequency**: Quarterly

Gross Domestic Product(GDP): Economic output, affecting overall spending capacities (Finkelstein et al., 2012).

Federal Funds Effective Rate: Reflects interest rates, which can influence health-related investments and insurance premiums (Chandra et al., 2014).

Real Disposable Personal Income Per Capita: Affects disposable income and spending on healthcare (Hurst et al., 2014).

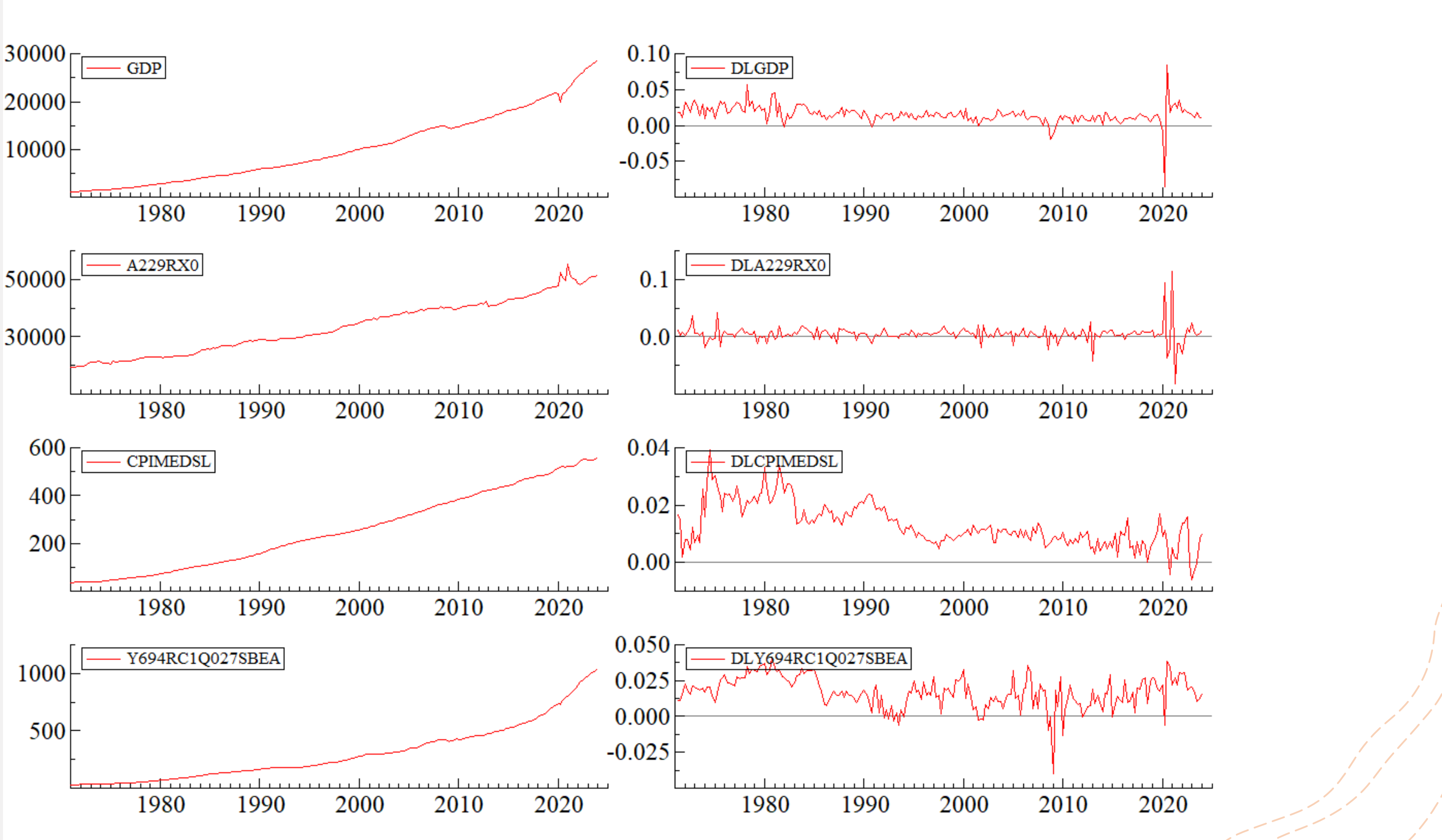
Unemployment Rate(UNRATE): A higher unemployment rate can lead to lower health spending, particularly if individuals lose employer-sponsored healthcare (Chakraborty et al., 2020).

Consumer Price Index for Medical Care): Represents the inflation rate specifically for medical services, directly impacting the cost of healthcare (Ginsburg, 2009).

R&D Expenditure: Reflects investments in medical research, potentially affecting the healthcare services available (Cutler et al., 2007).

CPI for all items: A general inflation metric that could influence overall spending trends across sectors, including healthcare (Janke et al., 2015).

Data Treatment- Independent Variables



Linear Autometrics with IIS and SIS

First Step

```
EQ(20) Modelling DLDHLCRG3Q086SBEA by OLS
       The dataset is: C:\Users\drvis\OneDrive - Babson College\Documents\ECN7510\Project Data\DATASET.xlsx
       The estimation sample is: 1972-07-01 - 2024-01-01

                          Coefficient  Std.Error  t-value  t-prob Part.R^2
DLDHLCRG3Q086SBEA_1          0.268582    0.06770     3.97  0.0001   0.0825
DLDHLCRG3Q086SBEA_2          0.202738    0.06855     2.96  0.0035   0.0476
II#1979-04-01             -0.00841778   0.002657    -3.17  0.0018   0.0542
SI#1981-01-01               0.0123533   0.002828     4.37  0.0000   0.0983
SI#1981-04-01              -0.0128784   0.003161    -4.07  0.0001   0.0867
SI#1982-01-01               0.0115385   0.003169     3.64  0.0004   0.0704
SI#1982-04-01              -0.0102578   0.002790    -3.68  0.0003   0.0717
Constant               U  -0.00253564   0.001055    -2.40  0.0173   0.0319
DLGDP                  U   -0.0110021    0.03430   -0.321  0.7488   0.0006
DLGDP_1                U    0.0341266    0.03596    0.949  0.3439   0.0051
DLGDP_2                U   0.00258022    0.02075    0.124  0.9012   0.0001
FEDFUNDS               U  0.000455102  0.0002335     1.95  0.0528   0.0213
FEDFUNDS_1             U  0.000308044  0.0003366    0.915  0.3614   0.0048
FEDFUNDS_2             U -0.000368299  0.0002416    -1.52  0.1292   0.0131
DLA229RX0              U    0.0174830    0.01655     1.06  0.2922   0.0063
DLA229RX0_1            U    0.0194367    0.01694     1.15  0.2528   0.0075
DLA229RX0_2            U   0.00313322    0.01535    0.204  0.8385   0.0002
UNRATE                 U  9.71592e-05  0.0005149    0.189  0.8505   0.0002
UNRATE_1               U  0.000457040  0.0006830    0.669  0.5043   0.0026
UNRATE_2               U -0.000307140  0.0005170   -0.594  0.5532   0.0020
DLCPIMEDSL             U     0.342911    0.05750     5.96  0.0000   0.1689
DLCPIMEDSL_1           U   -0.0696063    0.06468    -1.08  0.2833   0.0066
DLCPIMEDSL_2           U    0.0519369    0.06150    0.844  0.3996   0.0041
DLY694RC1Q027SBEA      U  -0.00511059    0.02403   -0.213  0.8318   0.0003
DLY694RC1Q027SBEA_1U       -0.0123632    0.02352   -0.526  0.5999   0.0016
DLY694RC1Q027SBEA_2U       -0.0116479    0.02435   -0.478  0.6330   0.0013
CPALTT01USM657N        U   0.00171021  0.0008038     2.13  0.0348   0.0252
CPALTT01USM657N_1      U  -3.77424e-05  0.0007904  -0.0478  0.9620   0.0000
CPALTT01USM657N_2      U   0.00123165  0.0008266     1.49  0.1380   0.0125
EPIDEMIC               U   0.00129519   0.001640    0.790  0.4307   0.0036
EPIDEMIC_1             U  -0.00141004   0.002223   -0.634  0.5267   0.0023
EPIDEMIC_2             U  0.000933227   0.001593    0.586  0.5587   0.0020

sigma                  0.00252127  RSS              0.00111243645
R^2                      0.919455  F(31,175) =      64.44 [0.000]**
Adj.R^2                  0.905187  log-likelihood         962.141
no. of observations           207  no. of parameters           32
mean(Y)                 0.0118368  se(Y)               0.00818812

AR 1-2 test:       F(2,173)   =   3.5705 [0.0302]*
ARCH 1-1 test:     F(1,205)   =  0.86095 [0.3546]
Normality test:    Chi^2(2)   =   3.5250 [0.1716]
Hetero test:       F(51,152)  =   1.6354 [0.0118]*
RESET23 test:      F(2,173)   =   4.5880 [0.0114]*
```

Linear Autometrics with IIS and SIS

Results

```
EQ(22) Modelling DLDHLCRG3Q086SBEA by OLS
       The dataset is: C:\Users\drvis\OneDrive - Babson College\Documents\ECN7510\Project Data\DATASET.xlsx
       The estimation sample is: 1972-07-01 - 2024-01-01

                      Coefficient  Std.Error  t-value  t-prob Part.R^2
DLDHLCRG3Q086SBEA_1      0.275178    0.05766     4.77  0.0000   0.1036
DLDHLCRG3Q086SBEA_2      0.234814    0.05346     4.39  0.0000   0.0892
FEDFUNDS              0.000408770  7.539e-05     5.42  0.0000   0.1299
DLCPIMEDSL               0.314763    0.04474     7.04  0.0000   0.2008
II#1979-04-01         -0.00883239   0.002558    -3.45  0.0007   0.0571
SI#1981-01-01           0.0117778   0.002602     4.53  0.0000   0.0942
SI#1981-04-01          -0.0112383   0.002904    -3.87  0.0001   0.0706
SI#1982-01-01           0.0109626   0.002920     3.75  0.0002   0.0668
SI#1982-04-01         -0.00956261   0.002620    -3.65  0.0003   0.0633
Constant            U -0.000522309  0.0003809    -1.37  0.1719   0.0095

sigma               0.00250839  RSS            0.00123952408
R^2                   0.910253  F(9,197) =       222 [0.000]**
Adj.R^2               0.906153  log-likelihood       950.944
no. of observations        207  no. of parameters         10
mean(Y)              0.0118368  se(Y)             0.00818812

AR 1-2 test:      F(2,195)  =   1.2243 [0.2962]
ARCH 1-1 test:    F(1,205)  =  0.55351 [0.4577]
Normality test:   Chi^2(2)  =   7.7119 [0.0212]*
Hetero test:      F(10,193) =  0.87422 [0.5583]
RESET23 test:     F(2,195)  =   3.6873 [0.0268]*
```

Results-

R-squared (R^2): 0.910- Explains 91% of the variance in the dependent variable, indicating a strong fit for time-series data.

Adjusted R^2: 0.906- Accounts for unnecessary variables, confirming the model is well-specified.

Residual Sum of Squares (RSS): 0.00124- Low RSS suggests minimal unexplained variance.

Autocorrelation (AR 1-2 Test): No evidence of residual autocorrelation, a favorable result.

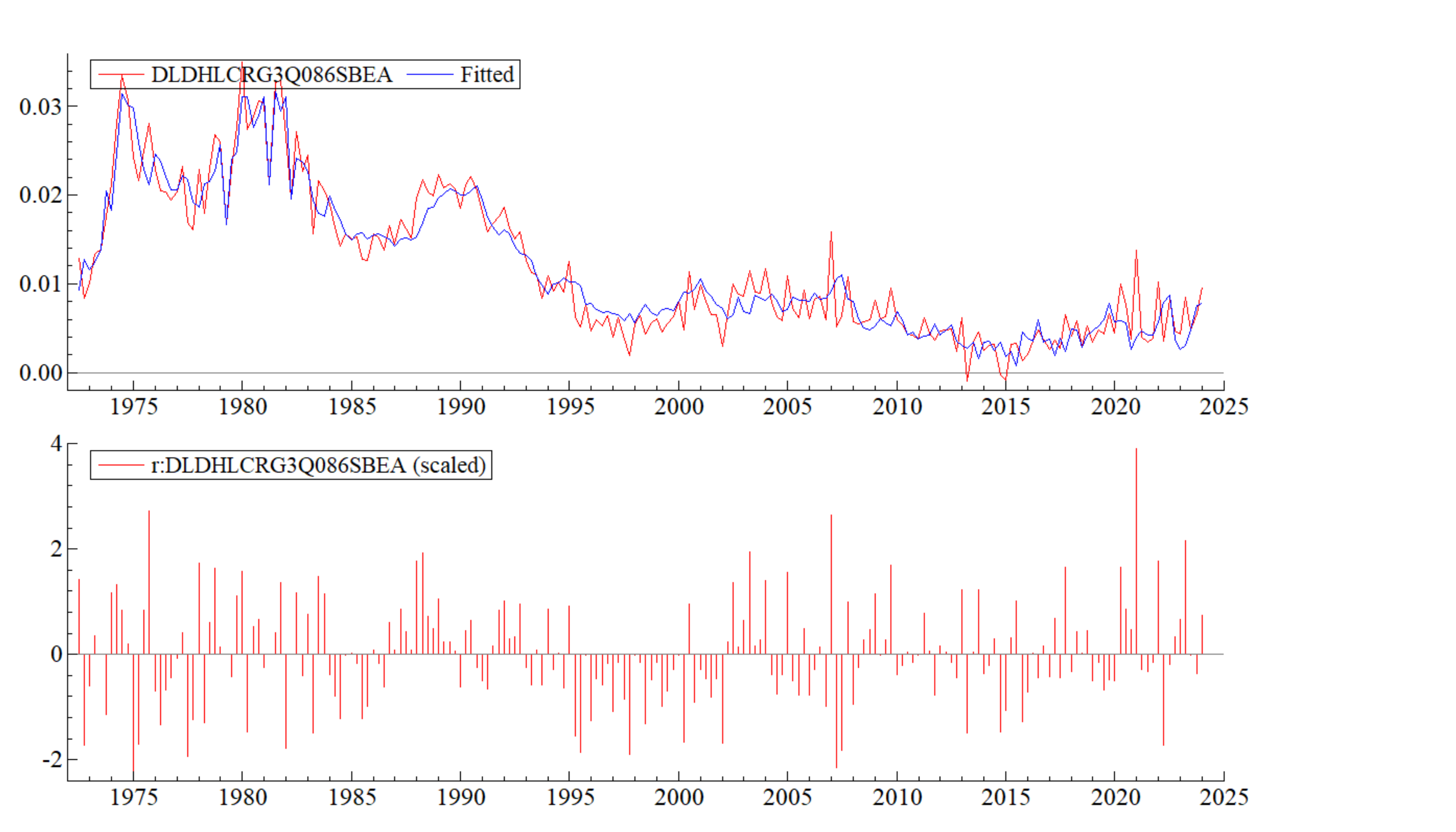
ARCH Effect (ARCH 1-1 Test): No heteroskedasticity, confirming stable residual variance.

Normality Test: Residuals deviate slightly from normality, which could require further analysis.

Heteroscedasticity Test: Stable variance across residuals.

RESET Test: Indicates possible model misspecification, suggesting the need for additional predictors or transformations.

Model Fit


DLDHLCRG3Q086SBEA
Fitted
0.03
0.02
0.01
0.00
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
r:DLDHLCRG3Q086SBEA (scaled)
4
2
0
-2
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025

Bias Correction Codes

```
//Code for Bias Correction
#include <oxstd.h>

main()
{
    //Insert coefficient estimates here:
    decl beta = <-0.00883239; 0.0117778; -0.112383; 0.0109626; -0.00956261>;
    //Insert estimated t-statistics here:
    decl t = <-3.45; 4.53; -3.87; 3.75; -3.65>;

    decl M = rows(beta);
    decl k, c_alpha, beta_1step = zeros(M,1), beta_2step = zeros(M,1);

    //Choose significance level and sample size
    decl p_a = 0.001;
    decl T = 207;

    c_alpha = quant(1-(p_a/2), T);

    for (k = 0; k < M; ++k)
            {
                    decl db = beta[k][];
                    decl dt = t[k][];
                    decl dr = (densn(c_alpha-dt)-densn(-c_alpha-dt)) / (1-probn(c_alpha-dt)+probn(-c_alpha-dt));
                    decl dtbar = dt - dr;
                    decl drbar = (densn(c_alpha-dtbar)-densn(-c_alpha-dtbar)) / (1-probn(c_alpha-dtbar)+probn(-c_alpha-dtbar));
                    beta_1step[k][] = fabs(dt).> c_alpha .? db .* (1 - (dr ./ dt)) .: 0;
                    beta_2step[k][] = fabs(dt).> c_alpha .? db .* (1 - (drbar ./ dt)) .: 0;
            }
    println("Uncorrected Coefficients, 1-step corrected coefficients and 2-step corrected coefficients",
    beta~beta_1step~beta_2step);

}
```

```
//Code for Bias Correction
#include <oxstd.h>

main()
{
    //Insert coefficient estimates here:
    decl beta = <0.275178; 0.234814; 0.000408770; 0.314763>;
    //Insert estimated t-statistics here:
    decl t = <4.77; 4.39; 5.42; 7.04>;

    decl M = rows(beta);
    decl k, c_alpha, beta_1step = zeros(M,1), beta_2step = zeros(M,1);

    //Choose significance level and sample size
    decl p_a = 0.01;
    decl T = 207;

    c_alpha = quant(1-(p_a/2), T);

    for (k = 0; k < M; ++k)
            {
                    decl db = beta[k][];
                    decl dt = t[k][];
                    decl dr = (densn(c_alpha-dt)-densn(-c_alpha-dt)) / (1-probn(c_alpha-dt)+probn(-c_alpha-dt));
                    decl dtbar = dt - dr;
                    decl drbar = (densn(c_alpha-dtbar)-densn(-c_alpha-dtbar)) / (1-probn(c_alpha-dtbar)+probn(-c_alpha-dtbar));
                    beta_1step[k][] = fabs(dt).> c_alpha .? db .* (1 - (dr ./ dt)) .: 0;
                    beta_2step[k][] = fabs(dt).> c_alpha .? db .* (1 - (drbar ./ dt)) .: 0;
            }
    println("Uncorrected Coefficients, 1-step corrected coefficients and 2-step corrected coefficients",
    beta~beta_1step~beta_2step);

}
```

Bias Correction- Results

```
---------------- Ox at 15:48:05 on 03-Dec-2024 ----------------

Ox 9.30 (Windows_64/Parallel) (C) J.A. Doornik, 1994-2024 (oxlang.dev)
Uncorrected Coefficients, 1-step corrected coefficients and 2-step corrected coefficients
      0.27518      0.27296      0.27277
      0.23481      0.23035      0.22961
   0.00040877   0.00040820   0.00040819
      0.31476      0.31476      0.31476
```

```
Ox 9.30 (Windows_64/Parallel) (C) J.A. Doornik, 1994-2024 (oxlang.dev)
Uncorrected Coefficients, 1-step corrected coefficients and 2-step corrected coefficients
      0.27518      0.27296      0.27277
      0.23481      0.23035      0.22961
   0.00040877   0.00040820   0.00040819
      0.31476      0.31476      0.31476
--------------- Ox at 15:51:36 on 03-Dec-2024 ---------------
```

Bias Correction- Interpretation

1-step Corrected Coefficients:

The first iteration of bias correction, making a preliminary adjustment to reduce systematic bias.

2-step Corrected Coefficients:

A refined estimate after the second correction step, further minimizing bias.

For DLDHLCRG3Q086SBEA_1:

The uncorrected coefficient was 0.28, which reduced slightly to 0.27 after 2-step correction.

For SI#1981-01-01:

The uncorrected coefficient was 0.012, which dropped slightly to 0.011 after correction.

Generally, the changes in coefficients are small, suggesting that our OLS estimates were relatively robust, with minimal bias.

Non-linear Autometrics with IIS and SIS

Index Test for Non-Linearity

```
Index test coefficients in auxiliary regression (regressors concentrated out):
                Coefficient  Std.Error    t-value
Z0^2             7.0867e-05  7.243e-05     0.9785
Z1^2            -0.00010013  0.0001078    -0.9289
Z2^2              0.0001107  0.0001213     0.9126
Z3^2             8.6624e-05  0.0001044     0.8298
X0*|Z0|              0.2432     0.1477      1.647
X1*|Z1|            -0.25547    0.09997     -2.556
X2*|Z2|          0.00044182  0.0006699     0.6595
X3*|Z3|             0.11693      0.119     0.9822
X0*Z0^2           -0.052275    0.04135     -1.264
X1*Z1^2            0.034472    0.03848      0.896
X2*Z2^2         -0.00018766  0.0003172    -0.5917
X3*Z3^2           0.0015138     0.0429    0.03528
RSS = 0.00107712  sigma = 5.69905e-06

Testing for non-linearity using the new Index test based
 on pre-whitened and then orthogonalized regressors:
 Chi^2(12) =   29.656 [0.0031]** and F-form F(12,189) =   2.5900 [0.0033]**
```

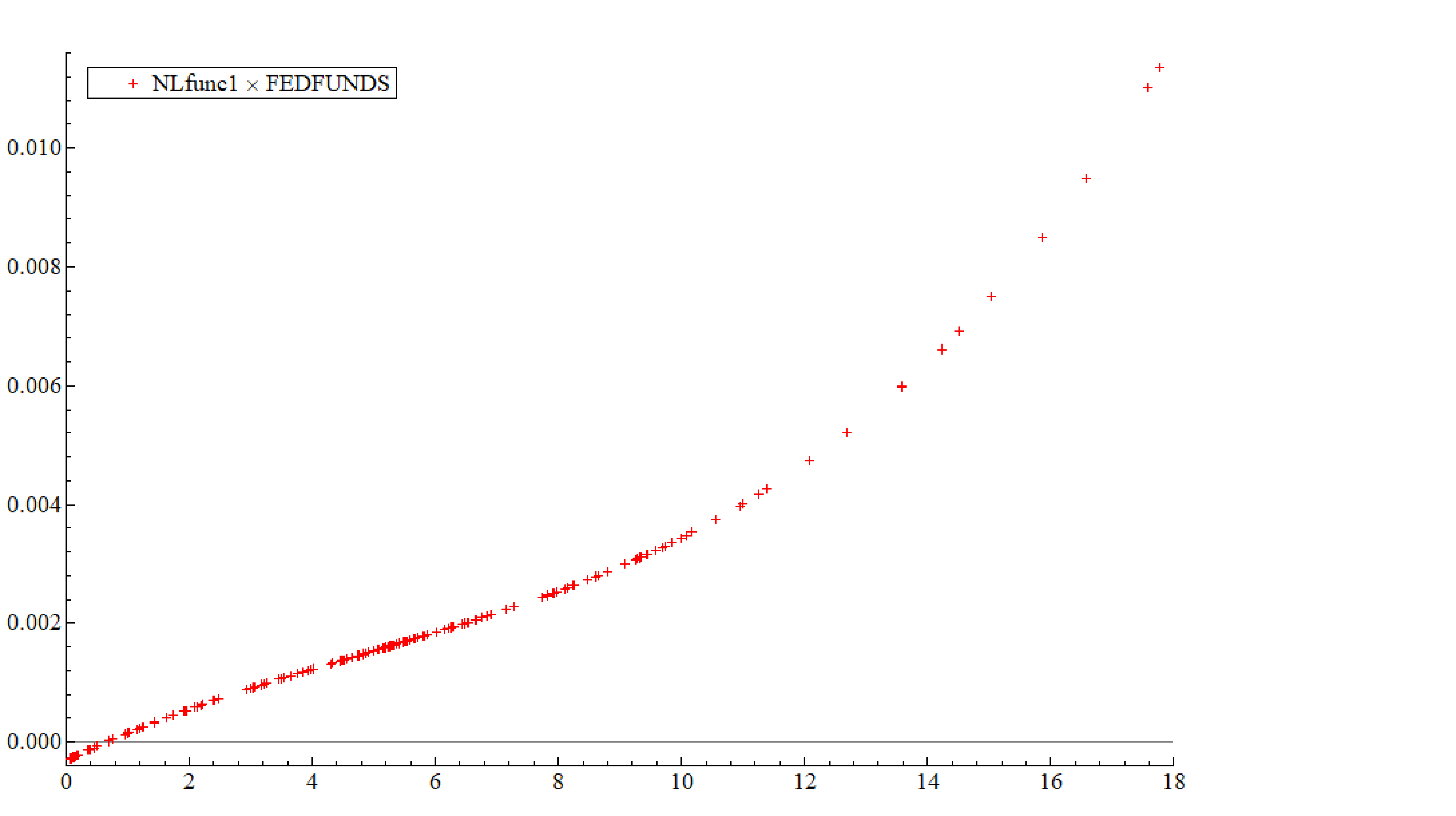
Inclusion of Non-Linear Variables- Results

```
EQ(16) Modelling DLDHLCRG3Q086SBEA by OLS
       The dataset is: C:\Users\drvis\OneDrive - Babson College\Documents\ECN7510\Project Data\DATASET.xlsx
       The estimation sample is: 1971-10-01 - 2024-01-01

                       Coefficient  Std.Error  t-value  t-prob Part.R^2
DLDHLCRG3Q086SBEA_1       0.199289    0.05392     3.70  0.0003   0.0652
DLDHLCRG3Q086SBEA_2       0.230095    0.05152     4.47  0.0000   0.0924
DLCPIMEDSL                0.305737    0.03655     8.37  0.0000   0.2631
CUBFEDFUNDS            2.74497e-06  8.313e-07     3.30  0.0011   0.0527
SQDLA229RX0               0.613229     0.1403     4.37  0.0000   0.0888
II#1975-10-01           0.00872871   0.002307     3.78  0.0002   0.0681
II#1978-10-01           0.00598451   0.002292     2.61  0.0097   0.0336
II#1979-04-01          -0.00689648   0.002294    -3.01  0.0030   0.0441
II#1981-04-01           -0.0140060   0.002689    -5.21  0.0000   0.1216
II#1982-04-01           -0.0108763   0.002361    -4.61  0.0000   0.0977
SI#1973-10-01          -0.00426790   0.001435    -2.97  0.0033   0.0432
SI#1974-10-01           0.00402289   0.001202     3.35  0.0010   0.0540
SI#1995-01-01           0.00223105  0.0005989     3.73  0.0003   0.0661
FEDFUNDS               0.000306625  8.139e-05     3.77  0.0002   0.0675

sigma                 0.00226052  RSS                 0.00100155110
R^2                     0.930309  log-likelihood            988.621
no. of observations          210  no. of parameters              14
mean(Y)                0.0118042  se(Y)                  0.00813579

AR 1-2 test:      F(2,194)  =  0.43322 [0.6490]
ARCH 1-1 test:    F(1,208)  =   1.1519 [0.2844]
Normality test:   Chi^2(2)  =   5.0469 [0.0802]
Hetero test:      F(15,189) =  0.73383 [0.7482]
RESET23 test:     F(2,194)  =  0.90708 [0.4054]
```

Index Test after inclusion of Non-linear terms

```
Index test coefficients in auxiliary regression (regressors concentrated out):
                 Coefficient  Std.Error     t-value
Z0^2              0.00014389  7.763e-05       1.853
Z1^2             -2.5799e-05  0.0001363     -0.1893
Z2^2             -0.00020857  0.0001134      -1.839
Z3^2              0.00012862  0.0001088       1.183
Z4^2              7.0615e-05  0.0001184      0.5966
Z5^2              0.00023368  0.0001908       1.225
X0*|Z0|             0.078398     0.1598      0.4907
X1*|Z1|            -0.048329     0.1065     -0.4538
X2*|Z2|              0.13522    0.09246       1.462
X3*|Z3|           1.4024e-05  9.368e-06       1.497
X4*|Z4|             -0.86847      1.648      -0.527
X5*|Z5|          -0.00024838  0.0008186     -0.3034
X0*Z0^2            -0.041022     0.0403      -1.018
X1*Z1^2           -0.0014876    0.04203    -0.03539
X2*Z2^2            -0.058015    0.03353       -1.73
X3*Z3^2          -6.9468e-06   4.41e-06      -1.575
X4*Z4^2            -0.087473      1.036    -0.08446
X5*Z5^2           0.00017051  0.0002155      0.7912
RSS = 0.000894876   sigma = 5.02739e-06

Testing for non-linearity using the new Index test based
 on pre-whitened and then orthogonalized regressors:
 Chi^2(18) =    22.355 [0.2166]    and F-form F(18,178) =    1.1782 [0.2835]
```

Non-Linear Plot: Fed Rates



Markov-switching estimates

2 Regime Markov Switching estimates

Switching(4) Modelling DLDHLCRG3Q086SBEA by MS(2)
The dataset is: C:\Users\drvis\OneDrive - Babson College\Documents\ECN7510\Project Data\DATASET.xlsx
The estimation sample is: 1971-04-01 - 2024-01-01

	Coefficient	Std.Error	t-value	t-prob
Constant(0)	-0.00355007	0.007175	-0.495	0.621
Constant(1)	-0.000280650	0.008482	-0.0331	0.974
DLGDP(0)	0.0384224	0.03394	1.13	0.259
DLGDP(1)	-9.69175e-05	0.06114	-0.00159	0.999
FEDFUNDS(0)	0.000676891	0.0004484	1.51	0.133
FEDFUNDS(1)	0.000647509	0.0002465	2.63	0.009
DLA229RX0(0)	-0.0373289	0.02988	-1.25	0.213
DLA229RX0(1)	0.0210617	0.05588	0.377	0.707
DLCPIMEDSL(0)	0.565090	0.07611	7.42	0.000
DLCPIMEDSL(1)	0.195478	0.07169	2.73	0.007
DLY694RC1Q027SBEA(0)	-0.00155964	0.04507	-0.0346	0.972
DLY694RC1Q027SBEA(1)	0.00673713	0.1729	0.0390	0.969
UNRATE(0)	0.000766014	0.001003	0.763	0.446
UNRATE(1)	0.000301509	0.0006382	0.472	0.637
CPALTT01USM657N(0)	0.00209207	0.004947	0.423	0.673
CPALTT01USM657N(1)	0.00123535	0.002665	0.464	0.643
EPIDEMIC(0)	-0.00281360	0.002430	-1.16	0.248
EPIDEMIC(1)	0.00234219	0.0009818	2.39	0.018

	Coefficient	Std.Error
sigma	0.00242964	0.0002657
p_{0|0}	0.963096	0.04273
p_{1|1}	0.980143	0.04537

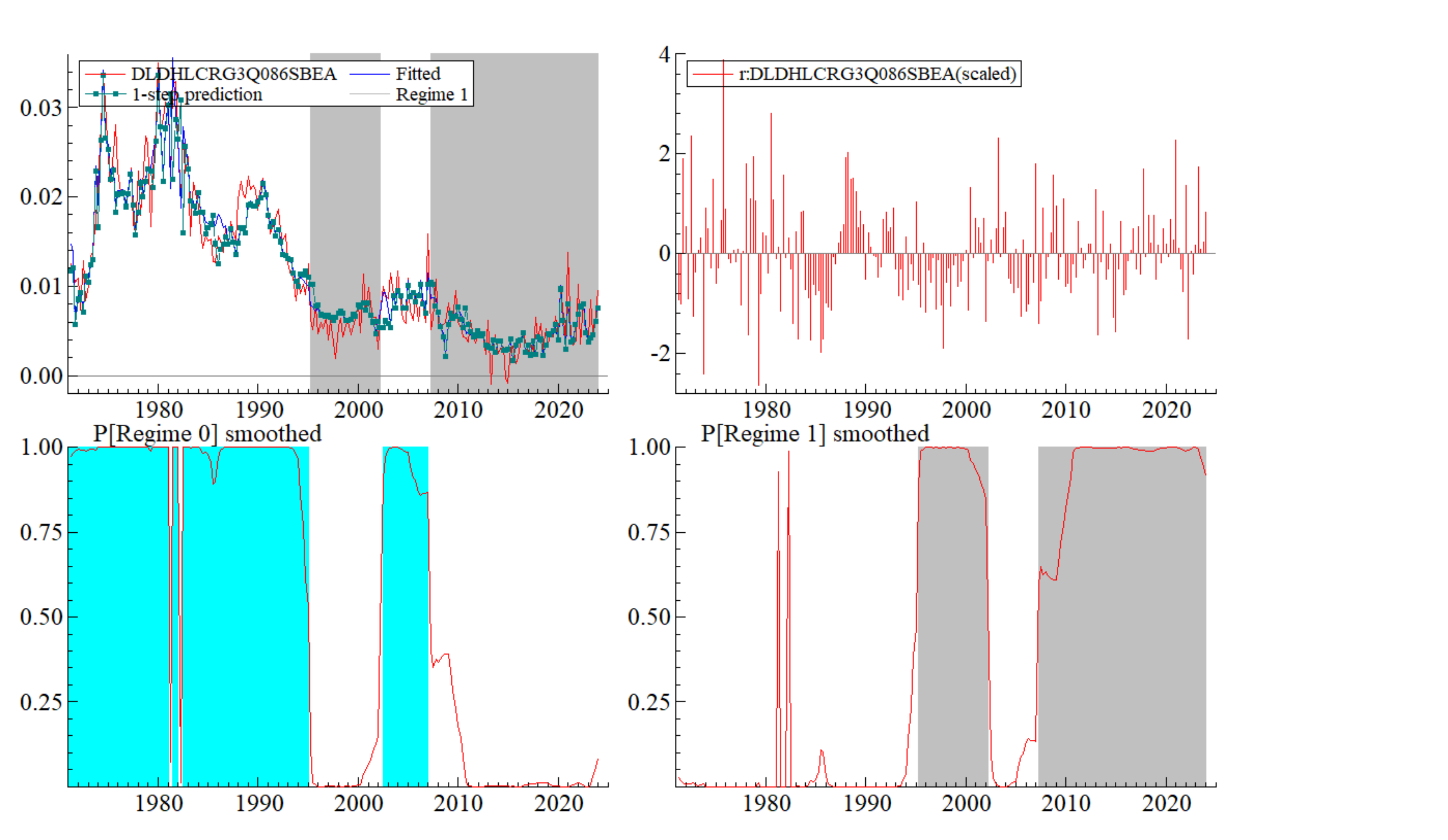
log-likelihood 950.392855
no. of observations 212 no. of parameters 21
AIC -8.76785713 SC -8.43536509
mean(DLDHLCRG3Q086SBEA) 0.0118059 se(DLDHLCRG3Q086SBEA) 0.0080973

Linearity LR-test Chi^2(11) = 52.984 [0.0000]** approximate upperbound: [0.0000]**

Transition probabilities p_{i|j} = P(Regime i at t+1 | Regime j at t)

	Regime 0,t	Regime 1,t
Regime 0,t+1	0.96310	0.019857
Regime 1,t+1	0.036904	0.98014

2 Regime Markov Switching estimates: Plot



Markov Switching Estimates: Interpretation

Key variable effects:

- **FEDFUNDS (Federal Funds Rate):**
  - Significant in Regime1 (p=0.009), indicating monetary policy influences health consumption during periods of economic stress or volatility.
  - Insignificant in Regime 0.
- **DLCPIMEDSL (Medical CPI):**
  - Strongly significant in both regimes, showing that healthcare price inflation is a dominant driver of changes in health expenditures regardless of the regime.
  - However, the effect is more pronounced in Regime 0 (β=0.565) compared to Regime 1 (β=0.195).
- **EPIDEMIC (Epidemic Indicator):**
  - Significant only in Regime 1Regime (p=0.018), reflecting its heightened impact during crisis-like periods.
- Other variables (e.g., GDP growth, unemployment rate) do not show significant effects in either regime, suggesting limited influence on short-term changes in health expenditures in this model.

Markov Switching Estimates: Interpretation

Model Fit and Diagnostics

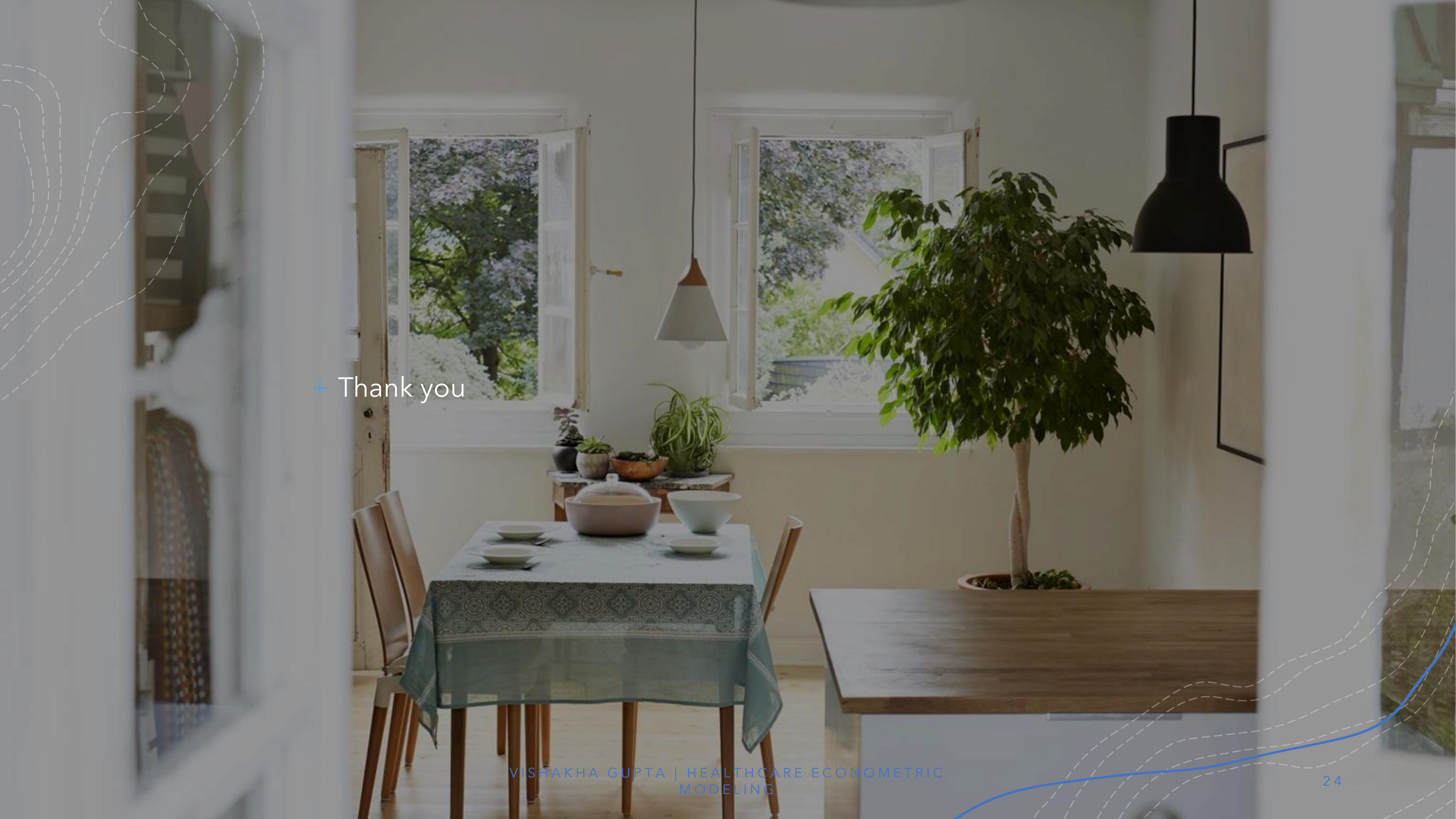
- **Log-Likelihood**: The high value of 950.39 indicates a good fit.
- **AIC/SC Criteria**: These values confirm model parsimony and fit relative to other potential models.
- **Linearity Test (Chi-Square):** $p<0.0001$ strongly rejects the null hypothesis of linearity, validating the use of a non-linear Markov-Switching framework.

Interpretation

- The results suggest distinct dynamics in healthcare spending under different economic conditions. Healthcare inflation (Medical CPI) is consistently important but has a dampened effect during periods of economic stress.
- Monetary policy (FEDFUNDS) and crisis-specific factors (EPIDEMIC) become more influential in Regime 1, underscoring their role in driving healthcare expenditures during volatile periods.

Future Implications

- **Policy Implications:** Highlight the sensitivity of healthcare spending to monetary policy and healthcare inflation in your report, especially under stressed economic conditions.
- **Forecasting:** Use the regime probabilities and distinct coefficients for scenario-based forecasting of healthcare spending.
- **Economic Insight:** Investigate potential causes of regime shifts, such as structural economic changes or major policy interventions.
- This model provides a robust framework for capturing non-linear dynamics and regime-specific behaviors in healthcare spending.



Thank you