Potential Constituents of the 30-Year Fixed US Mortgage Rate

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Introduction:

- Dependent Variable: 30-year fixed Mortgage Rates
    - Link to data: https://fred.stlouisfed.org/series/MORTGAGE30US

- Independent Variables: (all from fred.org)
    - Effective Federal Funds Rate
    - 10-Year Breakeven Inflation Rate
    - % Change of Commercial Banks MBS prices
    - % Change of Insured Unemployment Claims
    - National Financial Conditions Risk Index

Data:

Our dependent variable for this study is the 30-year fixed Mortgage Rates taken monthly from 2011 to 2021. Hence, our data is a time series which means that our units of observation span over a certain time period.

The independent variables being considered include the US effective federal funds rate, 10-year breakeven inflation rate, percent change of commercial bank mortgage-backed security (MBS) prices, percent change of insured unemployment claims, and national financial conditions risk index (all from fred.org). These as well are all time series data from 2011 to 2021. Hence, our initial regression function is described by;

$$mtger_t = \beta_0 + \beta_1(ffr) + \beta_2(infr) + \beta_3(logMBS) + \beta_4(logUnemp) + \beta_5(risk) + u_t$$

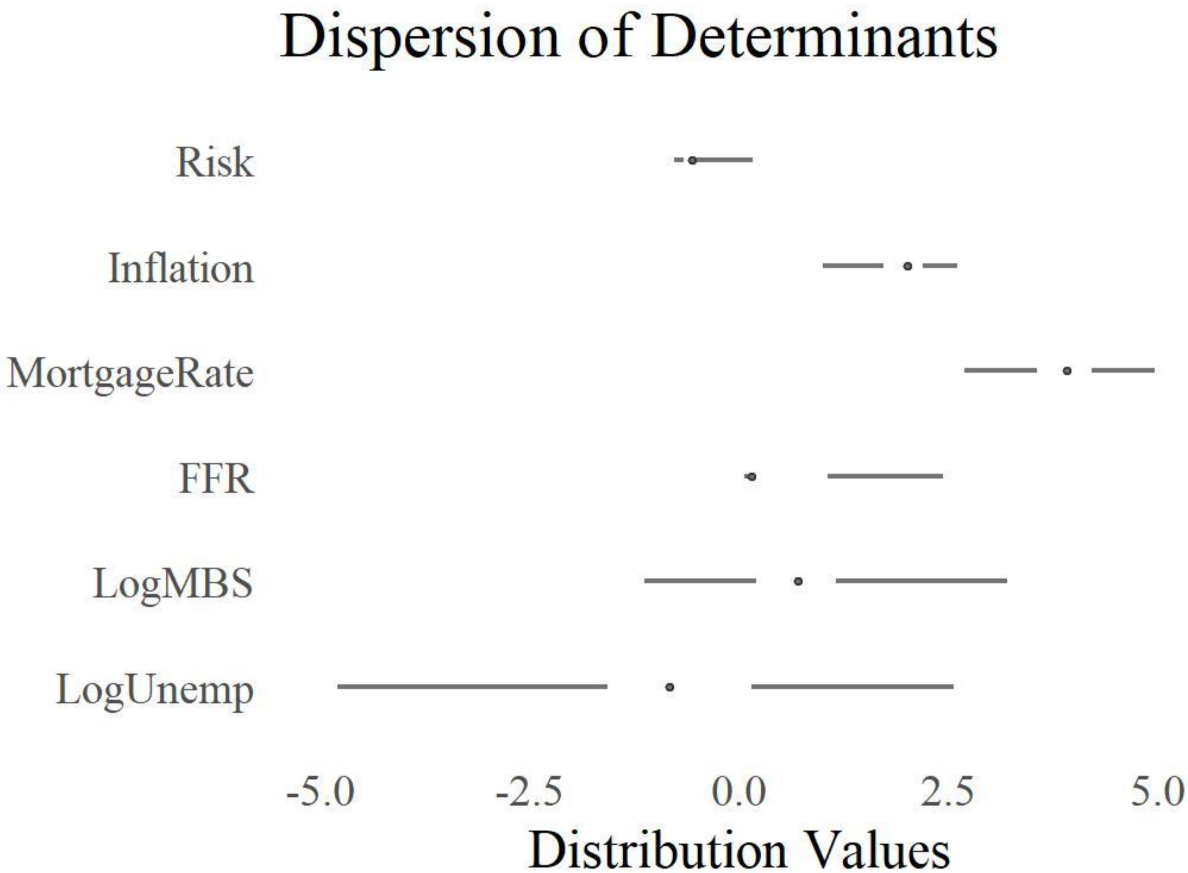
$$mtger = mortgage\ rate$$
$$ffr = federal\ funds\ rate$$
$$infr = inflation\ rate$$
$$logMBS = log\ of\ MBS\ prices$$
$$logUnemp = log\ of\ unemployment\ claims$$
$$risk = national\ financial\ risk\ index$$

Tabe 1 Summary statistics

Variable Name	Number of Observations	Mean	SD	25th Percentile	50th Percentile (median)	75th Percentile
Dependent Variable:						
Dependent: 30-year fixed Mortgage Rates	129	3.863	0.5251	3.550	3.904	4.196
Independent Variables:						
Effective Federal Funds Rate	129	0.5947	0.7579	0.0900	0.1400	1.0400
10-Year Breakeven Inflation Rate	129	1.9583	0.3342	1.7153	2.0040	2.1873
Log(Commercial Banks MBS prices)	129	0.7436	0.8185	0.2011	0.6962	1.1496
Log(Insured Unemployment Claims)	129	1.7972	34.364	-2.0138	-0.9733	0.1218
National Financial Conditions Risk Index	129	-0.5428	0.2045	-0.6776	-0.5804	-0.5104

Table 1 presents descriptive statistics of the independent and dependent variables used in the regression. The mean of the 30-year fixed Mortgage Rate from 2010 to 2021 is 3.863. The log of Insured Unemployment Claims has the highest standard deviation of 34.364. Hence, the descriptive statistics show a wide variation of the log of Insured Unemployment Claims from 2010 to 2021. The effective Federal Funds Rate is 3.550 at the lowest 25th percentile and as high as 1.0400 at the 75th percentile, with an average rate of 0.5947. The mean 10-Year Breakeven Inflation Rate is 1.9583 from 2010 to 2021.

In order to better understand and compare the distributions of these determinants, Visualization 1 represents these distributions in an easier to interpret manner, using minimalist Data Visualization Principles inspired by Edward Tufte (Tufte, 2001), as follows.



(Visualization 1)

Empirical Analysis:

After running our original model shown in the Appendix (with the same regression function mentioned in the Data section), we realized that the data needed to be changed into time series. We did this with the *ts* function in R. This yielded our 2nd Regression that accounted for the time series data (Regression 2). Using Regression 2, we tested our model for Overall Significance at a 1% level of significance. Since the p-value of the F-statistic in Regression 2 (p=3.217e-11) is smaller than 0.01, we reject the null hypothesis showing that at least one of the variables is significantly affecting Mortgage Rates at a 1% level of significance.

Next we tested for Heteroskedasticity using the Breusch-Pagan test as seen in Regression 3. Since the p-value for the F-statistic (p=1.039e-07) is smaller than 0.01, we reject the null hypothesis showing that there is Heteroskedasticity at a 1% level of significance. To strengthen the validity of our interpretation of heteroskedasticity, we conducted two more tests called White's Generalized and Special test for Heteroskedasticity. Regression 4 shows White's Generalized test, and since the p-value of the F-statistic (p=9.177e-08) is less than 0.01, we reject the null hypothesis showing that there is Heteroskedasticity at a 1% level of significance. In

Regression 5 shows Whites Special test for Heteroskedasticity, and the p-value of the F-statistic (p=0.01591) is larger than 0.01, therefore we do not reject the null hypothesis showing no Heteroskedasticity at a 1% level of significance. It is interesting to see that out of the three tests for Heteroskedasticity, White's Special Test reveals a different outcome. However, since the p-value of Regression 5 is very close to 0.01, using a 5% level of significance would make our conclusion the same as our previous 2 tests for Heteroskedasticity. In general it appears that our model is Heteroskedastic.

To account for Heteroskedasticity, we attempt to apply weighted least squares to account for the inconsistent error variance as shown in Regression 6. As you can see the R squared value rises to 0.5121 compared to Regression 2 (R Squared = 0.3921) which is a good indicator that heteroskedasticity is being managed.

We also test for Autocorrelation as seen in Regression 7 using exogenous regressors. Since the p-value of our lagged residual (lag(res1)) (p=<2e-16) is smaller than 0.01, We reject the null hypothesis, therefore showing we have Autocorrelation at a 1% level of significance. To correct Autocorrelation, we add a lagged ρY_{t-1} in Regression 8. However after doing this we get unreliable results since the R Squared became 1.

As a result of this, the next step is to test whether our data is non-stationary, as it looks like we have a unit root. In an Augmented Dickey-Fuller test of y_t (as shown in Figure 9), it is evident that we cannot reject the null hypothesis that $\gamma = 0$ at a 10% level of significance, signaling that MortgageRate is non-stationary, meaning that the traditional way of fixing First-Order Autocorrelation won't be enough to have accurate standard errors. The next step, then, is to test if ΔMortgageRate is non-stationary, requiring an ADF Test of diff(y), as shown in Figure 10. In this test, we can see a p-value of less than 0.01, indicating a rejection of the null hypothesis that $\gamma = 0$ at a 1% level of significance, indicating that our series is of Integrated Order One, as it took a First-Difference to fix the autocorrelation. In our final model, then, we must add $\Delta MortgageRate_{t-1}$ on the right side to account for First-Order Autocorrelation & Non-Stationary, as shown in Figure 11.

Final Model Table:

$$mtger_t = \beta_0 + \beta_1(ffr) + \beta_2(infr) + \beta_3(logMBS) + \beta_4(logUnemp) + \beta_5(risk) + \beta_6(\Delta MortgageRate_{t-1}) + u_t$$

$$mtger = mortgage\ rate$$
$$ffr = federal\ funds\ rate$$
$$infr = inflation\ rate$$
$$logMBS = log\ of\ MBS\ prices$$
$$logUnemp = log\ of\ unemployment\ claims$$
$$risk = national\ financial\ risk\ index$$
$$\Delta MortgageRate_{t-1} = Lag\ of\ Change\ in\ mtger$$

Independent Variables	Coefficient	Standard Error
FFR	0.3101	4.256 E-2
Inflation	0.5941	0.1033
LogMBS	-0.1815	4.248 E-2
LogUnemp	2.792 E-4	8.769 E-4
Risk	0.7053	0.1686
ΔMortgageRate$_{t-1}$	-0.3946	0.2656

- Degrees of Freedom: 121

Further Research:

In further research on the regression of Mortgage Rates, it would be best to not only add a number of extra explanatory variables (as many, many factors affect mortgage rates), but also to more thoroughly assess the significance of each explanatory variable and what else may be affecting their apparent significance or insignificance.

Appendix:

Figure 1: Original Model not in Time Series

```
Call:
lm(formula = MortgageRate ~ FFR + Inflation + LogMBS + LogUnemp +
    Risk, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.96979 -0.28986  0.02026  0.29146  1.12199

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  3.542e+00  2.789e-01  12.699  < 2e-16 ***
FFR          3.207e-01  5.271e-02   6.084 1.37e-08 ***
Inflation    3.920e-01  1.201e-01   3.263  0.00143 **
LogMBS      -2.228e-01  4.668e-02  -4.773 5.05e-06 ***
LogUnemp     1.976e-05  1.193e-03   0.017  0.98681
Risk         8.698e-01  2.014e-01   4.318 3.21e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4155 on 123 degrees of freedom
Multiple R-squared:  0.3982,	Adjusted R-squared:  0.3738
F-statistic: 16.28 on 5 and 123 DF,  p-value: 2.648e-12
```

Figure 2: Time Series

```
Call:
lm(formula = MortgageRate ~ FFR + Inflation + LogMBS + LogUnemp +
    Risk, data = tsdata)

Residuals:
     Min       1Q   Median       3Q      Max
-1.02775 -0.18959  0.04612  0.24540  0.85118

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.9467733  0.2820784  10.447  < 2e-16 ***
FFR          0.2597001  0.0500520   5.189 9.21e-07 ***
Inflation    0.6044275  0.1183926   5.105 1.32e-06 ***
LogMBS      -0.1549265  0.0457636  -3.385 0.000973 ***
LogUnemp     0.0006465  0.0011106   0.582 0.561637
Risk         0.4673413  0.2009158   2.326 0.021768 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3841 on 115 degrees of freedom
Multiple R-squared:  0.3921,	Adjusted R-squared:  0.3657
F-statistic: 14.84 on 5 and 115 DF,  p-value: 3.217e-11
```

Figure 3: Breusch-Pagan Test

```
Call:
lm(formula = res2 ~ FFR + Inflation + LogMBS + LogUnemp + Risk,
    data = tsdata)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.25038 -0.10395 -0.04758  0.07281  0.75245 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept) -0.5135663  0.1220168  -4.209 5.11e-05 ***
FFR         -0.0568195  0.0216506  -2.624  0.00986 ** 
Inflation    0.3031605  0.0512123   5.920 3.41e-08 ***
LogMBS       0.0150089  0.0197956   0.758  0.44989    
LogUnemp     0.0005009  0.0004804   1.043  0.29932    
Risk        -0.1728786  0.0869088  -1.989  0.04905 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1662 on 115 degrees of freedom
Multiple R-squared:  0.2954,	Adjusted R-squared:  0.2648 
F-statistic: 9.645 on 5 and 115 DF,  p-value: 1.039e-07
```

Figure 4: White’s Generalized Test

```
Call:
lm(formula = res2 ~ FFR + Inflation + LogMBS + LogUnemp + Risk + 
    (FFR^2) + (Inflation^2) + (LogMBS^2) + (LogUnemp^2) + (Risk^2) + 
    (FFR * Inflation) + (FFR * LogMBS) + (FFR * LogUnemp) + (FFR * 
    Risk) + (Inflation * LogMBS) + (Inflation * LogUnemp) + (Inflation * 
    Risk) + (LogMBS * LogUnemp) + (LogMBS * Risk) + (LogUnemp * 
    Risk), data = tsdata)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.27440 -0.09603 -0.03074  0.07220  0.65183 

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)  
(Intercept)        -0.485858   0.642431  -0.756    0.451  
FFR                 0.456702   0.386982   1.180    0.241  
Inflation           0.399918   0.293296   1.364    0.176  
LogMBS             -0.184219   0.168247  -1.095    0.276  
LogUnemp            0.003036   0.015693   0.193    0.847  
Risk                0.259251   1.265540   0.205    0.838  
FFR:Inflation      -0.237907   0.144879  -1.642    0.104  
FFR:LogMBS          0.005611   0.038609   0.145    0.885  
FFR:LogUnemp        0.003695   0.005514   0.670    0.504  
FFR:Risk            0.068217   0.246907   0.276    0.783  
Inflation:LogMBS   -0.012019   0.068133  -0.176    0.860  
Inflation:LogUnemp -0.004465   0.013860  -0.322    0.748  
Inflation:Risk     -0.005124   0.582625  -0.009    0.993  
LogMBS:LogUnemp     0.001180   0.002712   0.435    0.664  
LogMBS:Risk        -0.374536   0.144739  -2.588    0.011 *
LogUnemp:Risk       0.005128   0.015931   0.322    0.748  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1564 on 105 degrees of freedom
Multiple R-squared:  0.4304,	Adjusted R-squared:  0.3491 
F-statistic:  5.29 on 15 and 105 DF,  p-value: 9.177e-08
```

Figure 5: White's Special Test

```
Call:
lm(formula = res2 ~ predict + predict2, data = tsdata)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.26717 -0.10630 -0.06211  0.05324  0.79229 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)  
(Intercept)   4.5326     2.4902   1.820   0.0713 .
predict      -2.4102     1.2896  -1.869   0.0641 .
predict2      0.3270     0.1663   1.967   0.0515 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1887 on 118 degrees of freedom
Multiple R-squared:  0.06777,	Adjusted R-squared:  0.05197 
F-statistic: 4.289 on 2 and 118 DF,  p-value: 0.01591
```

Figure 6: Adding Weighted Least Squares

```
Call:
lm(formula = MortgageRate ~ FFR + Inflation + LogMBS + LogUnemp + 
    Risk, data = tsdata, weights = 1/sqrt(ols))

Weighted Residuals:
    Min      1Q  Median      3Q     Max 
-1.6929 -0.4306  0.1456  0.5164  1.5889 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)  2.7256401  0.2169862  12.561  < 2e-16 ***
FFR          0.2571171  0.0420554   6.114 1.37e-08 ***
Inflation    0.7075256  0.0977823   7.236 5.57e-11 ***
LogMBS      -0.1291774  0.0418524  -3.086  0.00254 ** 
LogUnemp     0.0006468  0.0007139   0.906  0.36687    
Risk         0.4489683  0.1525082   2.944  0.00392 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7556 on 115 degrees of freedom
Multiple R-squared:  0.5121,	Adjusted R-squared:  0.4909 
F-statistic: 24.14 on 5 and 115 DF,  p-value: < 2.2e-16
```

Figure 7: Exogenous Test for AR1

```
Call:
lm(formula = dyn(res1 ~ 0 + lag(res1)), data = tsdata)

Residuals:
       Min         1Q     Median         3Q        Max 
-9.247e-17 -6.040e-18  4.730e-19  5.511e-18  1.013e-16 

Coefficients:
          Estimate Std. Error   t value Pr(>|t|)    
lag(res1) 1.000e+00  5.484e-18 1.823e+17   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.259e-17 on 120 degrees of freedom
Multiple R-squared:      1,	Adjusted R-squared:      1 
F-statistic: 3.325e+34 on 1 and 120 DF,  p-value: < 2.2e-16

Warning message:
In summary.lm(result5) : essentially perfect fit: summary may be unreliable
```

Figure 8: Attempt to Fix AR1

```
Call:
lm(formula = MortgageRate ~ FFR + Inflation + LogMBS + LogUnemp + 
    Risk + lag(MortgageRate), data = tsdata, weights = 1/sqrt(ols))

Weighted Residuals:
       Min         1Q     Median         3Q        Max 
-4.276e-16 -4.540e-17 -1.440e-17  1.480e-17  3.396e-15 

Coefficients:
                   Estimate Std. Error    t value Pr(>|t|)    
(Intercept)       -1.206e-15  1.461e-16 -8.254e+00 3.03e-13 ***
FFR               -1.136e-16  2.116e-17 -5.368e+00 4.24e-07 ***
Inflation         -2.834e-16  5.157e-17 -5.496e+00 2.40e-07 ***
LogMBS             5.601e-17  1.904e-17  2.942e+00  0.00395 ** 
LogUnemp          -3.097e-19  3.132e-19 -9.890e-01  0.32487    
Risk              -1.793e-16  6.914e-17 -2.593e+00  0.01076 *  
lag(MortgageRate)  1.000e+00  4.077e-17  2.453e+16  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.303e-16 on 114 degrees of freedom
Multiple R-squared:      1,	Adjusted R-squared:      1 
F-statistic: 2.055e+32 on 6 and 114 DF,  p-value: < 2.2e-16
```

Figure 9: ADF Test on y_t

```
        Augmented Dickey-Fuller Test

data:  MortgageRate
Dickey-Fuller = -2.4858, Lag order = 5, p-value = 0.3746
alternative hypothesis: stationary
```

Figure 10: ADF Test on Δy_t

```
        Augmented Dickey-Fuller Test

data:  diff(MortgageRate)
Dickey-Fuller = -6.7587, Lag order = 1, p-value = 0.01
alternative hypothesis: stationary
```

Figure 11: Final model with Δy_{t-1} to account for FOAC & Non-Stationary.

```
Call:
lm(formula = dyn(MortgageRate ~ FFR + Inflation + LogMBS + LogUnemp +
    Risk + lag(diff(MortgageRate))), weights = 1/sqrt(varfunc))

Weighted Residuals:
     Min       1Q   Median       3Q      Max
-1.58171 -0.62102  0.09365  0.55977  1.62116

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)
(Intercept)             3.0375391  0.2334003  13.014  < 2e-16 ***
FFR                     0.3100612  0.0425618   7.285 3.59e-11 ***
Inflation               0.5940669  0.1033467   5.748 6.89e-08 ***
LogMBS                 -0.1814532  0.0424811  -4.271 3.89e-05 ***
LogUnemp                0.0002792  0.0008769   0.318    0.751
Risk                    0.7052947  0.1686250   4.183 5.48e-05 ***
lag(diff(MortgageRate)) -0.3946125  0.2656044  -1.486    0.140
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.7718 on 121 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.5027,    Adjusted R-squared:  0.478
F-statistic: 20.38 on 6 and 121 DF,  p-value: 2.225e-16
```

Works Cited:

Tufte, Edward. “Chapter 4: Data Ink and Graphical Redesign.” *The Visual Display of Quantitative Information*, vol. 2, Graphics Press, Cheshire, CT, 2001, pp. 91–105.