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INTEREST RATES IN ITALY (1980-2002)

OLS ESTIMATION USING THE TAYLOR RULE AND EXTENDING THE MODEL

INTRODUCTION

PROJECT OVERVIEW

AGENDA

1. Introduction
2. Taylor Model
3. Model Extension
4. Conclusion

Goal

Estimate an econometric model that relates short-term interest rates to inflation and other relevant explanatory variables for Italy in the years from 1980 to 2002. Formulate some economical hypothesis.

Methodology

Gather data about dependent and independent variable. Pre-process and clean the data. Run OLS regression following Taylor Model and test its accuracy. Eventually expand the model.

INTRODUCTION

DATA HANDLING AND CLEANING

- To proceed with the model, we **require data**. Our data collection involved sourcing data from various resources. Whenever possible, we opted for data provided by OECD or FED. In cases where this wasn't possible, we used other sources such as NASDAQ or Macroeconomic Trends. The code includes precise links specific to each piece of data.
- The folder data/raw contains the raw data that was extracted.
- After extraction, we had to **clean the data**. Since the data was from different sources, there were discrepancies in time spans, currencies, and technical aspects such as types. We accomplished this through a Jupyter Notebook named data_prep.ipynb. This is also where the links to the cleaned data are provided.
- The folder data/clean contains the clean and processed data.
- Once the data was ready, we proceeded to **create a dataframe** that contained all the different pieces of data in the same format. We accomplished this in the R script 30413_Italy.R, which is the same script used to develop the model.

TAYLOR MODEL
OVERVIEW

1 2 3 4

- The **Taylor Rule** as formulated by John B. Taylor and reported by Par Osterholm in the suggested paper is represented by the following formula:

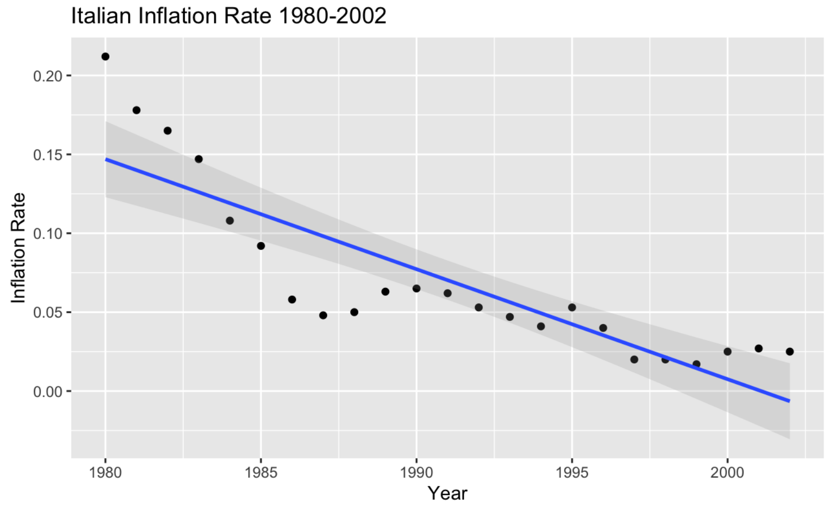
$$i_t = r^* + \pi_t + \alpha(\pi_t - \pi^*) + \beta(y_t - y_n)$$

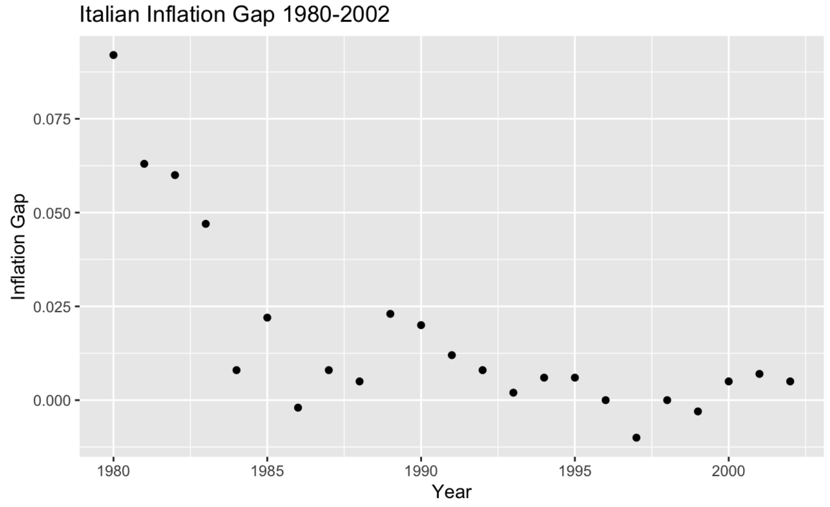
- Where i_t represents the central bank policy rate, r^* represents the equilibrium real interest rate, π_t represents the inflation rate, π^* represents the target inflation rate, y_t represents the output level and y_n represents the potential level of output.
- The model provides a rule-based approach to **monetary policy**, which is the process by which a central bank controls the supply of money and interest rates to promote economic growth and stability.
- The model assumes that the central bank has a target inflation rate and seeks to keep inflation close to that target. By setting interest rates in response to changes in inflation and output, the central bank can help stabilize the economy and promote sustainable growth.

TAYLOR MODEL

DESCRIPTIVE ANALYSIS – INFLATION AND INFLATION GAP

- The **inflation rate** in Italy during the period 1980-2002 was characterized by a downward trend: starting from the high inflation of the early 1980s, there was a gradual decline across the 1990s and early 2000s.
- During the early 1980s, Italy experienced very high inflation rates. This was due to a combination of factors, including high levels of public spending, wage indexation, and the 1979 oil crisis.
- Inflation remained high throughout the mid-1980s, until the late 1980s and early 1990s, when the Italian government implemented a series of measures to reduce it and stabilize the economy, such as fiscal austerity and wage restraint. As a result, inflation gradually declined in the 1990s, with average annual inflation rates falling to around 5% by the mid-1990s.
- The **inflation gap**, i.e., the difference between inflation and inflation target, has also declined over time, reflecting the effort by the government to contain inflation. Data about inflation target are retrieved from the paper *«La politica monetaria italiana negli anni '80 e '90: la revisione del modus operandi»* by Mario Sarcinelli.





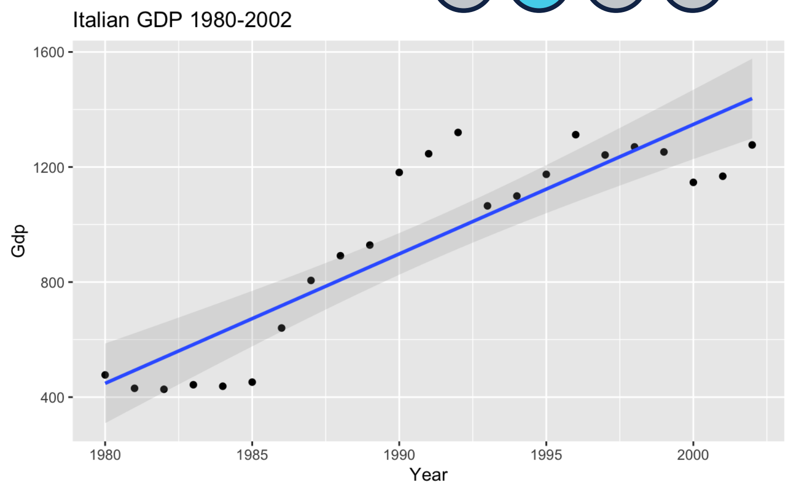
TAYLOR MODEL

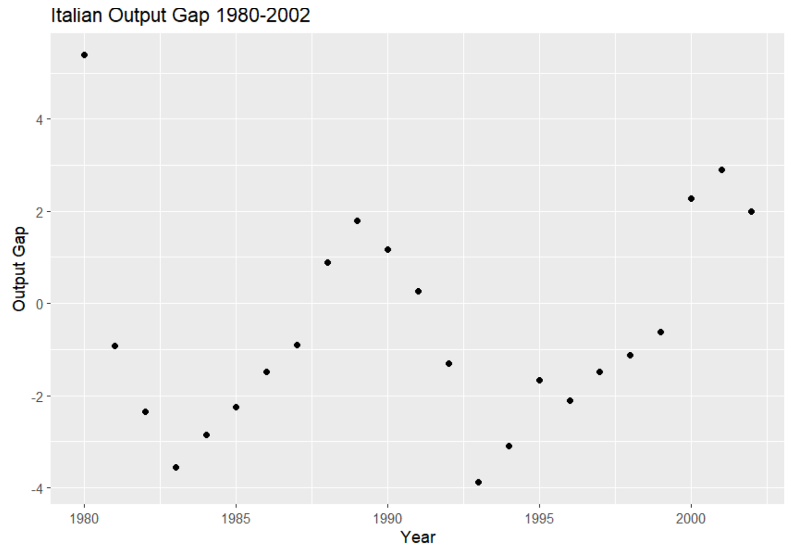
DESCRIPTIVE ANALYSIS – OUTPUT AND OUTPUT GAP

- The Italian **output**, also called GDP**,** has been steadily increasing from 1980 to 2002, almost tripling from \$400bn to \$1200bn.
- The **output gap** is defined as:

$$\frac{GDP - Potential\ GDP}{Potential\ GDP}$$

- In the 1980 it is very high, and this is reflected in a very high inflation. Afterwards, the output gap decreases, becoming negative, and the inflation decreases as well. In the period 1987-1991 the output gap becomes positive again, indeed we can see that the inflation rate slightly increases (see previous slide). In general, as the economic theory suggests, a positive output gap (GDP above its natural level) is linked to an increase in the inflation rate.

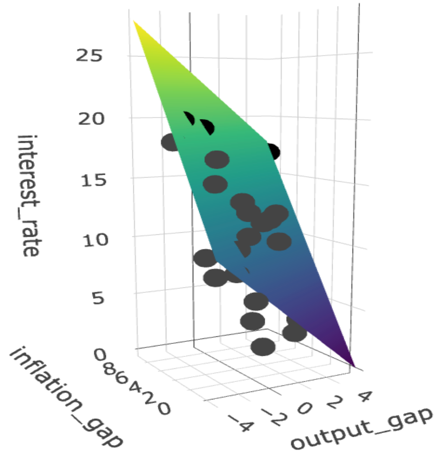




TAYLOR MODEL

OLS REGRESSION

- The significance of each regression coefficient separately from the other is tested with a t-test.
- According to the reported output, both output gap and inflation gap are **significant** (p-value <<< 0.001). In particular, the interest rate appears to be negatively related to the output gap and positively related to the inflation gap.
- The p-value associated with the F-statistic is also very small, so we reject the hypothesis that neither of the regressors is significant.
- Regression fit plot:



R output

```
> summary(taylor_reg)

Call:
lm(formula = interest_rate ~ output_gap + inflation_gap, data = df)

Residuals:
    Min      1Q  Median      3Q     Max 
-4.9268 -1.6281 -0.7271  2.5028  5.0446 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)     7.7358     0.7825   9.886 3.83e-09 ***
output_gap     -1.0875     0.2789  -3.900  0.00089 ***
inflation_gap   1.7243     0.2566   6.720 1.54e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.906 on 20 degrees of freedom
Multiple R-squared:  0.713,	Adjusted R-squared:  0.6842 
F-statistic: 24.84 on 2 and 20 DF,  p-value: 3.798e-06
```

TAYLOR MODEL

TESTING THE ASSUMPTIONS 1/2

LINEARITY

Ramsey Test

```
data:  taylor_reg
RESET = 3.1544, df1 = 1, df2 = 19, p-value = 0.09174
data:  taylor_reg
RESET = 0.58167, df1 = 1, df2 = 19, p-value = 0.455
data:  taylor_reg
RESET = 1.4924, df1 = 1, df2 = 19, p-value = 0.2368
```

H_0: $E(Y) = X\beta$
H_1: $E(Y) = f(X;\beta)$

With different powers being tested (2°, 3° and 4°), we never reject the null hypothesis at a significance level of 5%.

NORMALITY OF ERRRORS

Jarque-Bera Test

```
data:  residuals(taylor_reg)
X-squared = 0.91323, df = 2, p-value = 0.6334
```

H_0: $\varepsilon \sim N(0, \sigma^2)$
H_1: ε *not normal*

We do not reject the null hypothesis at a significance level of 5%.

HOMOSCEDASTICITY

Goldfeld-Quandt Test

```
data:  taylor_reg
GQ = 1.532, df1 = 7, df2 = 6, p-value = 0.6902
alternative hypothesis: variance decreases from segment 1 to 2
data:  taylor_reg
GQ = 1.532, df1 = 7, df2 = 6, p-value = 0.3098
alternative hypothesis: variance increases from segment 1 to 2
data:  taylor_reg
GQ = 1.532, df1 = 7, df2 = 6, p-value = 0.6195
alternative hypothesis: variance changes from segment 1 to 2
```

$$H_0: \sigma^2{}_i = \sigma^2$$
$$H_1: \sigma^2{}_i = cX_i^2$$

With different alternatives being tested (i.e. variance increases, decreases and changes), we never reject the null hypothesis at a significance level of 5%.

TAYLOR MODEL

TESTING THE ASSUMPTIONS 2/2

NO CORRELATION

Durbin-Watson Test

```
data:  taylor_reg
DW = 0.89974, p-value = 0.0004722
alternative hypothesis: true autocorrelation is greater than 0
```

Breusch-Godfrey Test

```
data:  taylor_reg
LM test = 6.7369, df = 1, p-value = 0.009444

data:  taylor_reg
LM test = 7.8504, df = 2, p-value = 0.01974

data:  taylor_reg
LM test = 7.9437, df = 3, p-value = 0.04719

data:  taylor_reg
LM test = 8.2186, df = 4, p-value = 0.08389

data:  taylor_reg
LM test = 8.2808, df = 5, p-value = 0.1414
```

DURBIN-WATSON

H_0: ε_t *uncorrelated (time lag one year)*

$$H_1: \varepsilon_t = \rho\varepsilon_{t-1} + u_t$$

We reject the null hypothesis at a significance level of 5%.
We must investigate about serial correlation up to higher orders.

BREUSCH-GODREY

H_0: ε_t *uncorrelated (at higher time lags)*
H_1: ε_t *correlated*

We reject the null hypothesis of uncorrelation up to time lag of 3 years (included) at a significance level of 5%.

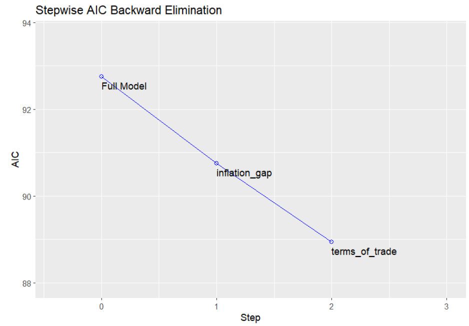
MODEL EXTENSION

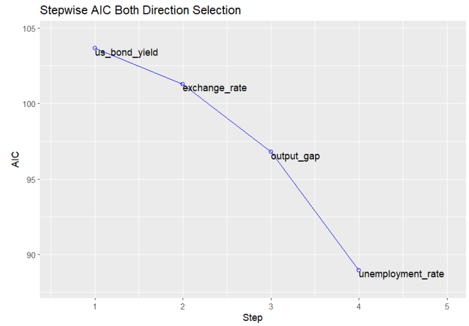
OVERVIEW

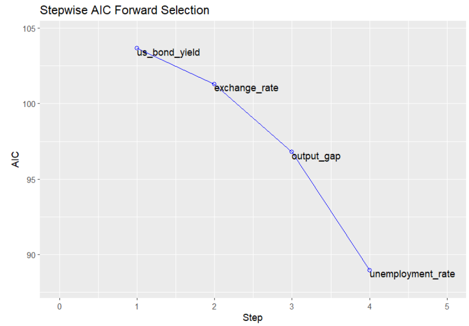
- The previous tests' evidences of **serial correlation** hints to a likely problem of omitted variables, hence we proceed to extend the model. The extra regressors added include: USD/Lira exchange rate, unemployment rate, US interest rate, US GDP, and terms of trade. The choice of these regressors was based on Svensson's observations quoted in Osterholm's paper.
- While **adding regressors** clearly increased the R^2 of the model, it also carried the risk of overfitting. Therefore we proceeded first with a Ridge and a Lasso regression and, followingly, with some variable selection techniques. We found the latters to have a higher explainability power.
- After having explored many different models (see R script), and performed **variable selection** through best subset selection, forward selection, backward selection and both direction selection, we found the best model to be the 4 regressors model (according to Akaike's Information Criterion (AIC) and the adjusted R^2):

$$interest\ rate = \beta_0 + \ \beta_1 \cdot output_{gap} + \beta_2 \cdot exchange\ rate + \beta_3 \cdot unemployment\ rate + \beta_4 \cdot US\ bond\ rate$$

- As the graphs shows, the lowest AIC was reached by adding the aforementioned parameters and by removing the inflation gap and the terms of trade.





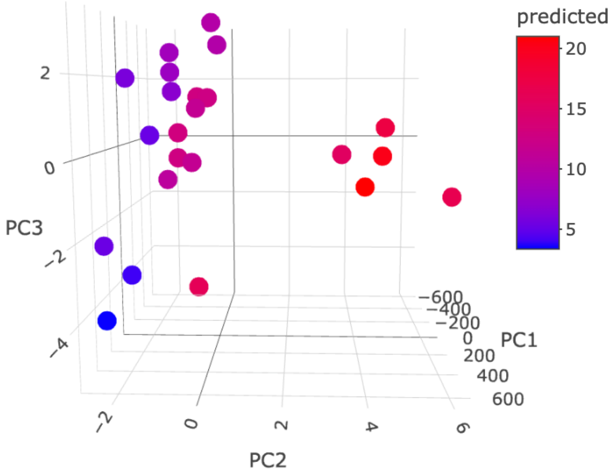


MODEL EXTENSION

OLS REGRESSION

1 2 3 4

- The significance of each regression coefficient separately from the other is tested with a t-test.
- According to the reported output, all the regressors are **significant** at a 99% confidence level. In particular, the interest rate appears to be negatively related to output gap, exchange rate, and unemployment rate, while it is positively related to the inflation gap.
- The p-value associated with the F-statistic is also very small, so we reject the null hypothesis that every regressor is not significant.
- PCA visualization:



R output

```
> summary(taylor_subset)

Call:
lm(formula = interest_rate ~ us_bond_yield + exchange_rate +
    output_gap + unemployment_rate, data = df)

Residuals:
     Min       1Q   Median       3Q      Max
-2.26312 -0.86273  0.07576  0.74893  2.57825

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)       20.794809   5.766902   3.606 0.002021 **
us_bond_yield      0.953055   0.219319   4.346 0.000390 ***
exchange_rate     -0.004489   0.001117  -4.018 0.000806 ***
output_gap        -0.630709   0.155526  -4.055 0.000742 ***
unemployment_rate -1.166830   0.376207  -3.102 0.006158 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.457 on 18 degrees of freedom
Multiple R-squared:  0.9351,    Adjusted R-squared:  0.9207
F-statistic: 64.82 on 4 and 18 DF,  p-value: 1.927e-10
```

MODEL EXTENSION

TESTING THE ASSUMPTIONS

1 2 3 4

LINEARITY ✓

Ramsey Test *

```
data:  taylor_subset
RESET = 2.6465, df1 = 1, df2 = 17, p-value = 0.1222
data:  taylor_subset
RESET = 1.6062, df1 = 1, df2 = 17, p-value = 0.2221
data:  taylor_subset
RESET = 1.9652, df1 = 1, df2 = 17, p-value = 0.1789
```

HOMOSCEDASTICITY ✓

Breusch-Pagan Test

```
data:  taylor_subset
BP = 1.3793, df = 4, p-value = 0.8478
```

NORMALITY OF ERRRORS ✓

Jarque-Bera Test

```
data:  residuals(taylor_subset)
X-squared = 0.40057, df = 2, p-value = 0.8185
```

NO CORRELATION ✗

Breusch-Godfrey Test **

```
data:  taylor_reg
LM test = 6.7369, df = 1, p-value = 0.009444
data:  taylor_reg
LM test = 7.8504, df = 2, p-value = 0.01974
data:  taylor_reg
LM test = 7.9437, df = 3, p-value = 0.04719
data:  taylor_reg
LM test = 8.2186, df = 4, p-value = 0.08389
data:  taylor_reg
LM test = 8.2808, df = 5, p-value = 0.1414
```

* Tested on 2°, 3° and 4° powers

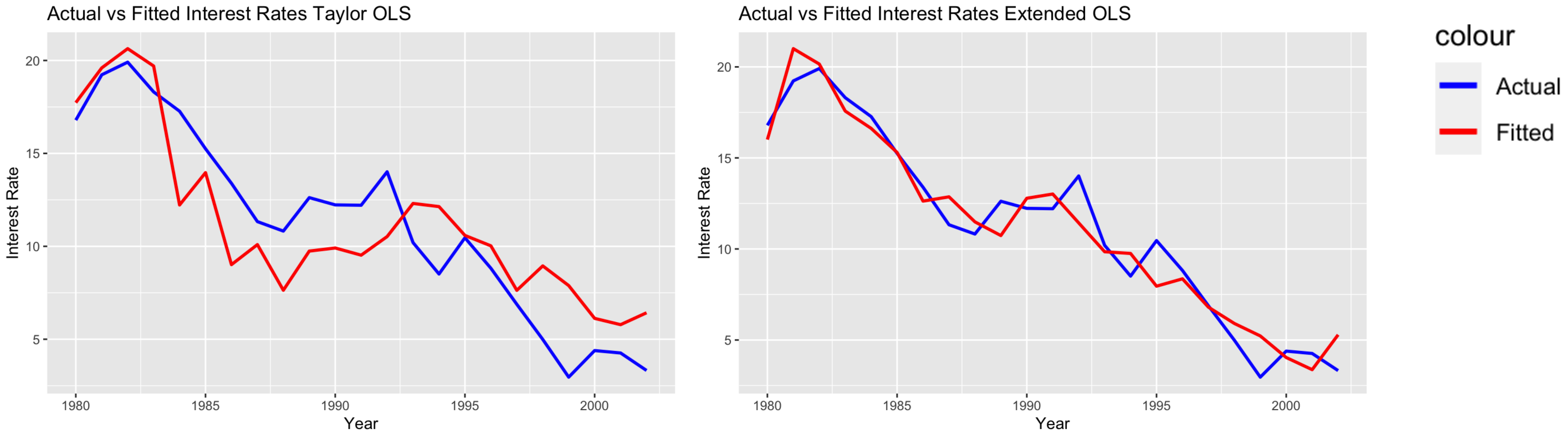
** Tested up to time lag of 5 years

CONCLUSION

MODEL COMPARISON

1 2 3 4

- The tests evidence that the problem of serial correlation was not removed. This is a hint to the fact that we should proceed by looking for some addional or alternative regressors. Another way that could be chosen is the one of running a GLS regression that will take account of this problem.
- However, the adjusted R^2 of the final model is equal to 0.9207, a **considerable improvement** with respect to the adjusted R^2 of the first model (0.6842), as it can be evinced from the following plots:



CONCLUSION

ECONOMICAL INTERPRETATION

- After formulating and testing several models, we could conclude that the Taylor Rule does not correctly model Italy's monetary policy in the last decades of the 20th century. This conclusion also aligns with Sarcinelli's thesis that inflation was a much **less influential** factor in determining monetary policies with respect to others such as the exchange rate.
- After best subset selection we also verify the fact that some of the regressors quoted by Svensson (foreign output, foreign interest rates) prove to be **more effective** in shaping the interest rate than others in the Taylor rule (interest gap).
- The final model follows also the principles of traditional **macroeconomic theory**. More specifically the implications of the uncovered interest parity are verified (as the foreign interest rate increases or the exchange rate decreases, the interest rate increases), as well as those of the IS-LM-PC model (as the unemployment rate decreases, the interest rate increases).

Uncovered interest parity

$$i_t \approx i_t^* - \frac{E_{t+1}^e - E_t}{E_t}$$

IS-LM relation

$$IS: Y = C(Y - T) + I(Y, i) + G$$
$$LM: i = \bar{\imath}$$

Phillip's curve

$$\pi_t = \pi_t^e - \alpha(u_t - u_n)$$

THANK YOU

Dorsi Tancredi
Morosini Alessandro
Vacca Francesco