ECONOMETRICS PROJECT

Forecasting Danish GDP growth

GROUP 10

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1. Descriptive analysis

- **Country**: Denmark
- **Period:** 1973-2019
- **Dependent variable:** GDP growth (real terms): stationary

- **Initial regressors (percentage change between t and t-1):**
  - «Central Bank Policy Rate»
  - «CPI»
  - «Economic Activity, Industrial Production, Manufacturing, Index»
  - « Net Export»
  - « Unemployment rate»
  - « Population»
  - «International liquidity, Total Reserves Excluding Gold ($)» →

	GDP GROWTH REAL
Mean	0.018454
Median	0.019570
Maximum	0.059246
Minimum	-0.049065
Std. Dev.	0.019937
Skewness	-0.631600
Kurtosis	4.339033
Jarque-Bera	6.636167
Probability	0.036222
Sum	0.867318
Sum Sq. Dev.	0.018285
Observations	47

2. Alternative model specification

1. **LASSO Regression Model** (Table 1)
   - Plug the 7 regressors into the model
   - Coefficient on «Net Export» shrinked to 0→ removed from the model

$$y_t = \beta_1 cb_t + \beta_2\, pop_t + \beta_3 int_t + \beta_4 un_t + \beta_5 eco_t + \beta_6 cpi_t$$

2. **STATIC Model** (Table 2)
   - ***General to specific***: from 7 regressors to 4 : «CPI», «Economic Activity», «Unemployment», « Population».
   - Apparently better model: higher Adj.R^2 and lower Information Criteria

$$y_t = \beta_1 cpi_t + \beta_2 pop_t + \beta_3 un_t + \beta_4 Economic_t + \varepsilon_t$$

3. **DYNAMIC Model** (Table 3)
   - **ARDL Automatic selection process: ran 4 times, each time with different** selection criteria (AIC, BIC, Hannan-Quinn and Adj.R^2), and also considered the MAPEs resulting from forecasting
   - The model minimizing the **«AIC»** was chosen: 1 lag for unemployment rate and AR(1)

$$y_t = \beta_1 y_{t-1} + \beta_2 cpi_t + \beta_3 pop_t + \beta_4 un_t + \beta_5 un_{t-1} + \beta_6 cb_t + \varepsilon_t$$

2. Alternative model specification

Table 1: LASSO Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CPI	0.098706	0.057226	1.724853	0.0948
ECONOMIC	0.339536	0.064088	5.297930	0.0000
CB	0.004312	0.010002	0.431168	0.6694
POPULATION	2.684924	0.790279	3.397439	0.0019
UNEMPLOYMENT	-0.016815	0.009809	-1.714232	0.0968
INTERNATIONAL	0.005761	0.006029	0.955644	0.3469

R-squared	0.748623	Mean dependent var	0.017989
Adjusted R-squared	0.706726	S.D. dependent var	0.022082
S.E. of regression	0.011958	Akaike info criterion	-5.863762
Sum squared resid	0.004290	Schwarz criterion	-5.599842
Log likelihood	111.5477	Hannan-Quinn criter.	-5.771647
Durbin-Watson stat	1.897692		

Table 2: Static Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CPI__	0.121858	0.050954	2.391535	0.0228
ECONOMIC	0.319773	0.054770	5.838510	0.0000
POPULATION	2.885553	0.731163	3.946524	0.0004
UNEMPLOYMENT__	-0.021136	0.008568	-2.466810	0.0192

R-squared	0.740841	Mean dependent var	0.017989
Adjusted R-squared	0.716545	S.D. dependent var	0.022082
S.E. of regression	0.011756	Akaike info criterion	-5.944387
Sum squared resid	0.004423	Schwarz criterion	-5.768441
Log likelihood	110.9990	Hannan-Quinn criter.	-5.882977
Durbin-Watson stat	1.851218		

INTERPRETATION: a 1% increase in X leads to an average β% increase in real GDP growth, ceteris paribus

2. Alternative model specification

Table 3: Dynamic Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP GROWTH REAL(-1)	0.144238	0.125248	1.151626	0.2596
ECONOMIC	0.222024	0.054987	4.037746	0.0004
POPULATION	0.871752	1.357916	0.641978	0.5263
UNEMPLOYMENT	-0.042962	0.011040	-3.891565	0.0006
UNEMPLOYMENT (-1)	0.020972	0.009396	2.232043	0.0341
CPI	-0.287835	0.145290	-1.981111	0.0578
CPI (-1)	0.300636	0.166178	1.809127	0.0816
C	0.009047	0.006026	1.501437	0.1448

R-squared	0.851379	Mean dependent var	0.018824
Adjusted R-squared	0.812848	S.D. dependent var	0.021820
S.E. of regression	0.009440	Akaike info criterion	-6.290145
Sum squared resid	0.002406	Schwarz criterion	-5.934637
Log likelihood	118.0775	Hannan-Quinn criter.	-6.167424
F-statistic	22.09582	Durbin-Watson stat	2.431130
Prob(F-statistic)	0.000000		

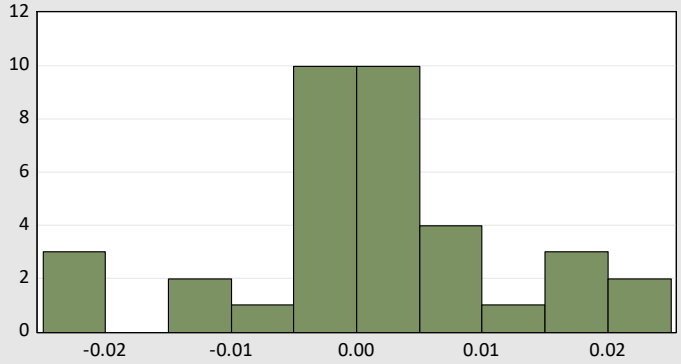
*Note: p-values and any subsequent tests do not account for model selection.

Comment: Adjusted R^2 improves, ICs decrease

3. Diagnostic checks

STATIC

- **Normality of errors:** **Histogram**



Series: Residuals	
Sample 1974 2009	
Observations 36	
Mean	0.001340
Median	0.002479
Maximum	0.023966
Minimum	-0.021776
Std. Dev.	0.011159
Skewness	-0.238781
Kurtosis	2.990068
Jarque-Bera	0.342247
Probability	0.842718

- **Serial Correlation:** **Breusch-Godfray Test**

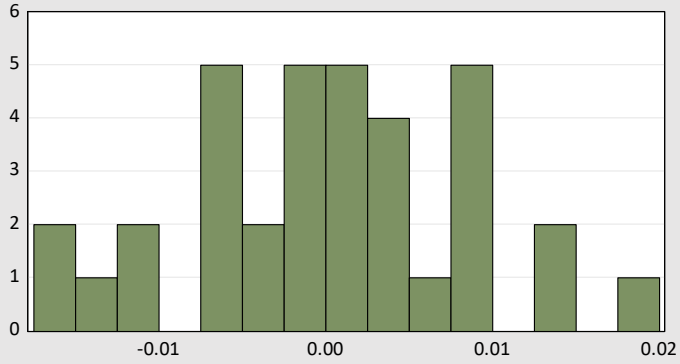
  Ho: No serial correlation at up to 1 lags: p-value: 0.6524

- **Homoskedasticity:** **Breusch-Pagan Test**

  Ho: Homoskedasticity: p-value: 0.25

DYNAMIC

- **Normality of errors:** **Histogram**



Series: Residuals	
Sample 1975 2009	
Observations 35	
Mean	-2.60e-18
Median	0.000687
Maximum	0.019603
Minimum	-0.015882
Std. Dev.	0.008412
Skewness	0.109720
Kurtosis	2.683027
Jarque-Bera	0.216747
Probability	0.897293

- **Serial Correlation:** **Breusch-Godfray Test**

  Ho: No serial correlation at up to 1 lag: p-value: 0.1363

- **Homoskedasticity:** **Breusch-Pagan Test**

  Ho: Homoskedasticity: p-value: 0.9095

4. Economic Hypotheses

- **Variable 1: CPI**
  - **Hypotheses:**
    - Moderate inflation (moderate CPI increase) → Positive GDP growth (increased consumer spending)
    - High inflation (large CPI increase) → Negative GDP growth (reduced purchasing power)
    - Deflation (negative CPI change) → Negative GDP growth (consumers delay spending, businesses reduce investment)
- **Variable 2: Danish population**
  - **Hypothesis:** Increase in population growth → Positive GDP growth (more workforce participation and economic activity)
- **Variable 3: Central Bank Policy Rate**
  - **Hypothesis:**
    - Decrease in policy rate → Positive GDP growth (lower borrowing costs stimulate investment and spending)
    - Increase in policy rate → Negative GDP growth (higher borrowing costs dampen investment and spending)

*** All variables are expressed in terms of percentage change

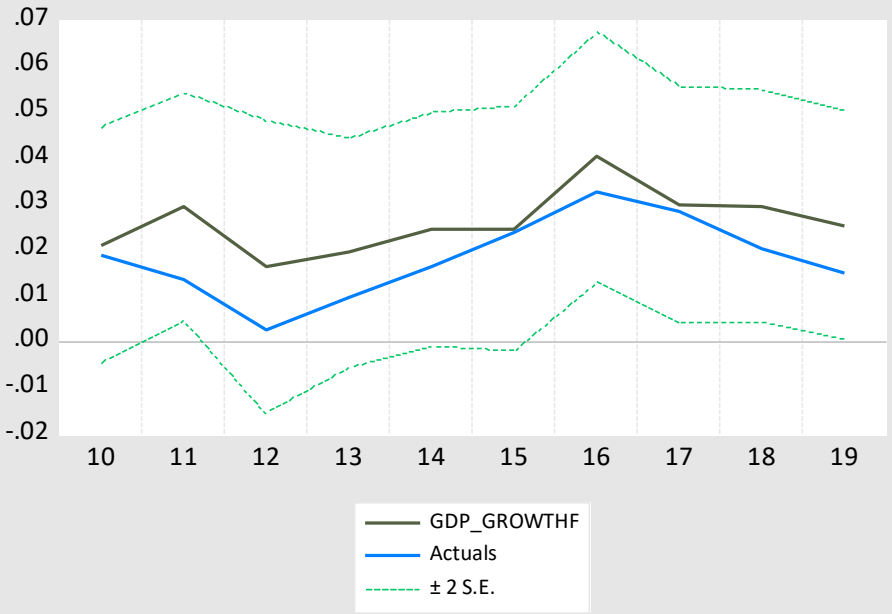
4. Economic Hypotheses

- **Variable 4: Unemployment**
  - **Hypothesis:** Increase in unemployment → Negative GDP growth (less consumer spending and reduced economic output)
- **Variable 5: Economic activity, industrial production, Manufacturing index**
  - **Hypothesis:** Increase in the index → Increase in GDP growth (Economic performance and progress in these three sectors)
- **Variable 6: International liquidity, total reserves excluding gold**
  - **Hypothesis:** Increase in liquidity→ Increase in GDP growth (International reserves, excluding gold, tend to provide economic stability, improve import capacity, and support investor confidence)

5. Forecasts

- **Training Sample:** **1973-2009**
- **Evaluation sample:** **2010-2019**

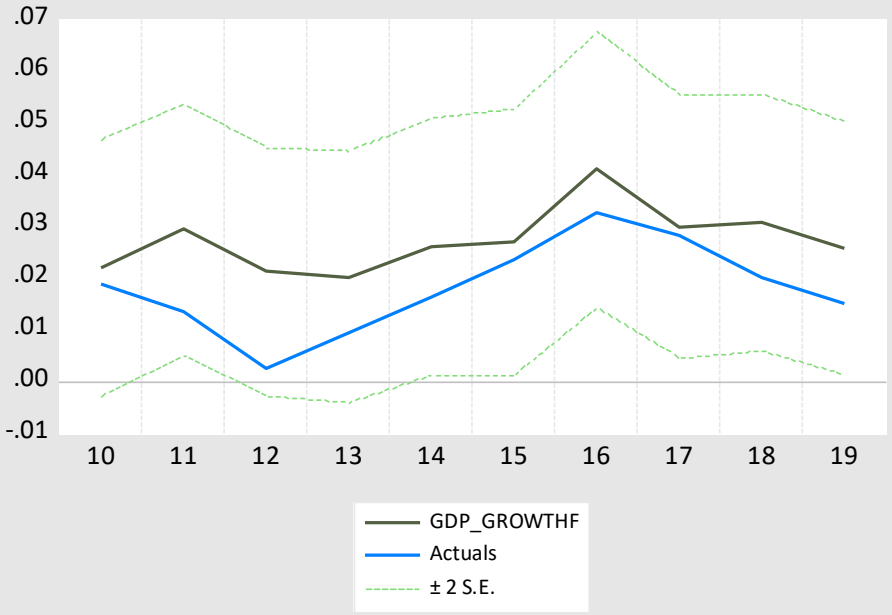
LASSO



Forecast: GDP_GROWTHF	
Actual: GDP_GROWTH_REAL	
Forecast sample: 2010 2019	
Included observations: 10	
Root Mean Squared Error	0.009320
Mean Absolute Error	0.007954
Mean Abs. Percent Error	105.0668
Theil Inequality Coef.	0.201029
Bias Proportion	0.728314
Variance Proportion	0.046174
Covariance Proportion	0.225512
Theil U2 Coefficient	1.376675
Symmetric MAPE	46.44822

5. Forecasts

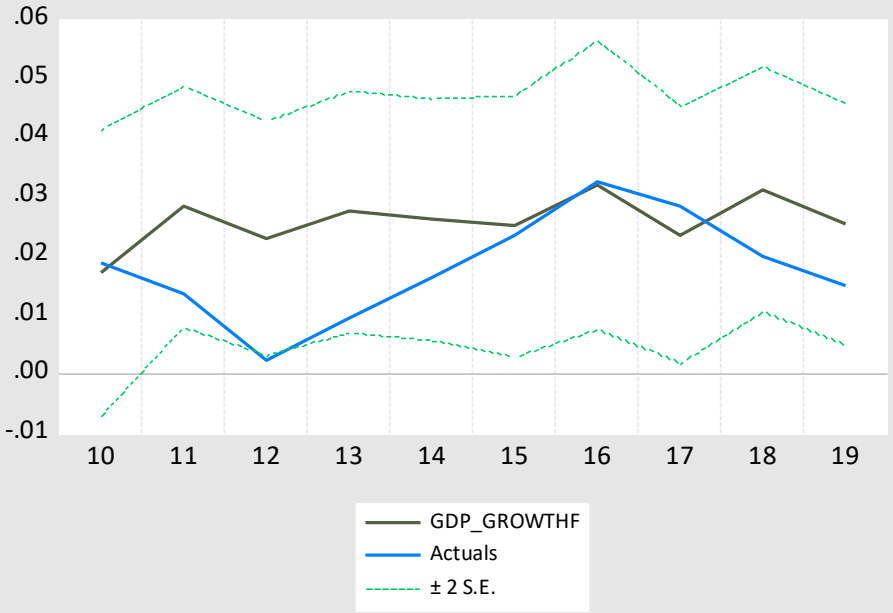
STATIC



Forecast: GDP_GROWTHF	
Actual: GDP_GROWTH_REAL	
Forecast sample: 2010 2019	
Included observations: 10	
Root Mean Squared Error	0.010684
Mean Absolute Error	0.009319
Mean Abs. Percent Error	131.3060
Theil Inequality Coef.	0.224681
Bias Proportion	0.760759
Variance Proportion	0.060387
Covariance Proportion	0.178854
Theil U2 Coefficient	1.522918
Symmetric MAPE	50.77956

5. Forecasts

DYNAMIC



Forecast: GDP_GROWTHF	
Actual: GDP_GROWTH_REAL	
Forecast sample: 2010 2019	
Included observations: 10	
Root Mean Squared Error	0.011505
Mean Absolute Error	0.009334
Mean Abs. Percent Error	143.0008
Theil Inequality Coef.	0.250885
Bias Proportion	0.472164
Variance Proportion	0.139642
Covariance Proportion	0.388194
Theil U2 Coefficient	2.422465
Symmetric MAPE	51.15429

5. Forecasts

DIEBOLD MARIANO test

LASSO vs Static

Evaluation statistics

Forecast	RMSE	MAE	MAPE	SMAPE	Theil U1	Theil U2
STATICMODEL	0.010684	0.009319	131.3060	50.77956	0.224681	1.522918
STATICFROMLASSO	0.009320	0.007954	105.0668	46.44822	0.201029	1.376675
Mean square error	0.009969	0.008626	117.9864	48.66852	0.212383	1.447952

LASSO vs Dynamic

Evaluation statistics

Forecast	RMSE	MAE	MAPE	SMAPE	Theil U1	Theil U2
STATICFROMLASSO	0.009320	0.007954	105.0668	46.44822	0.201029	1.376675
DYNAMICMODELAIC	0.011505	0.009334	143.0008	51.15429	0.250885	2.422465
Mean square error	0.010540	0.008535	128.4074	48.40536	0.229460	2.053897

LASSO vs AR(2)

Lasso regression's forecast is better in MAPE sense.

Evaluation statistics

Forecast	RMSE	MAE	MAPE	SMAPE	Theil U1	Theil U2
AR2MODEL	0.010812	0.009062	132.1587	55.80130	0.276595	1.340452
STATICFROMLASSO	0.009320	0.007954	105.0668	46.44822	0.201029	1.376675
Mean square error	0.008686	0.006854	105.6764	42.60186	0.194743	1.358236

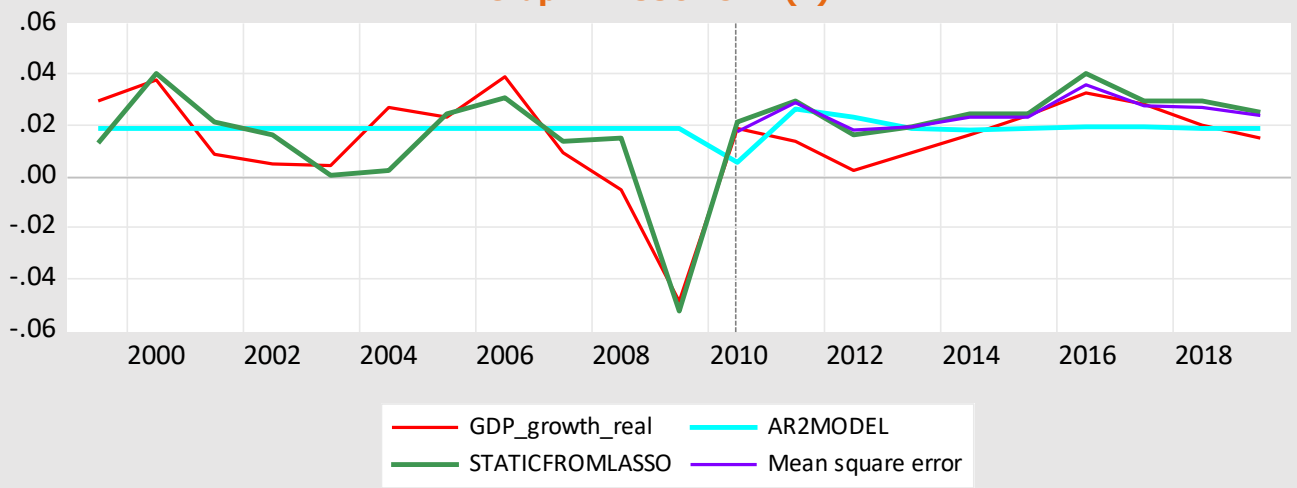
6. Comparison with AR(2)

Table 4: AR(2) Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.017202	0.006664	2.581354	0.0146
GDP_GROWTH_REAL(-1)	0.252255	0.195262	1.291876	0.2057
GDP_GROWTH_REAL(-2)	-0.160193	0.197222	-0.812249	0.4227

R-squared	0.064971	Mean dependent var	0.018824
Adjusted R-squared	0.006531	S.D. dependent var	0.021820
S.E. of regression	0.021749	Akaike info criterion	-4.736678
Sum squared resid	0.015137	Schwarz criterion	-4.603363
Log likelihood	85.89187	Hannan-Quinn criter.	-4.690658
F-statistic	1.111762	Durbin-Watson stat	1.816135
Prob(F-statistic)	0.341353		

Graph: LASSO vs AR(2)



Final comments

- To increase our sample size and improve our forecast and estimates, we could employ quarterly data (not found for all variables)
- Denmark joined the EU in 1973 – the starting period of our sample
- The ending year is 2019, as Covid-19 hit thereafter
- Data taken from: IMF – International Financial Statistic, Macrotrend, World Bank.