# DA Assignment 3

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## Introduction and data description

In this assignment I am interested in how demand may be correlated with commodity prices. I am going to analyze quarterly GDP of Austria, Brent oil price and Gold price as a commodity.

I obtained the data from different sources:

- quarterly GDP data: *OECD (2019), Quarterly GDP (indicator). doi: 10.1787/b86d1fc8-en (Accessed on 03 December 2019); https://data.oecd.org/gdp/quarterly-gdp.htm*
- Brent oil price data: *from U.S. Energy Information Administration, Crude Oil Prices: Brent - Europe [DCOILBRENTEU], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/DCOILBRENTEU, December 3, 2019.*
- Gold price data: *ICE Benchmark Administration Limited (IBA), Gold Fixing Price 10:30 A.M. (London time) in London Bullion Market, based in U.S. Dollars [GOLDAMGBD228NLBM], retrieved from FRED, Federal Reserve Bank of St. Louis;*

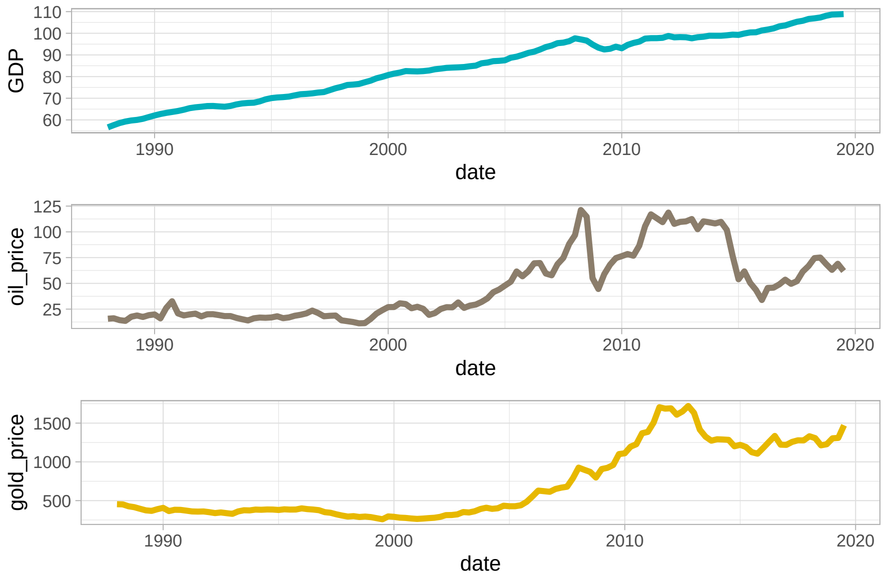
Price data were available in a more frequent time unit, so it is necessary to align them with GDP data in terms of their freuqency. To create quarterly data from commodity prices I created a new time variable with the as.yearqtr function, that shows the year and quarter of the original date. Then the price values were aggregated and the mean price was calculated for each quarter.

A new dataframe was created with only the quarterly time variable and the average commodity price for the respective time frame. The combined dataset of GDP and commodity prices has 127 observations between the years 1988 and 2019. There are no missing values in the dataset.

*Table 1: Variables of the dataset:*

| Variable name | Type | Description |
|---|---|---|
| date | qualitative, ordinal | Year and Quarter |
| GDP | quantitative | GDP Volume index of GDP per capita, OECD = 100 in 2015 |
| oil_price | qualitative | price in USD |
| gold_price | qualitative | price in USD |

Fig1: GDP over time; Fig 2: Brent oil price over time; Fig 3: Gold price over time



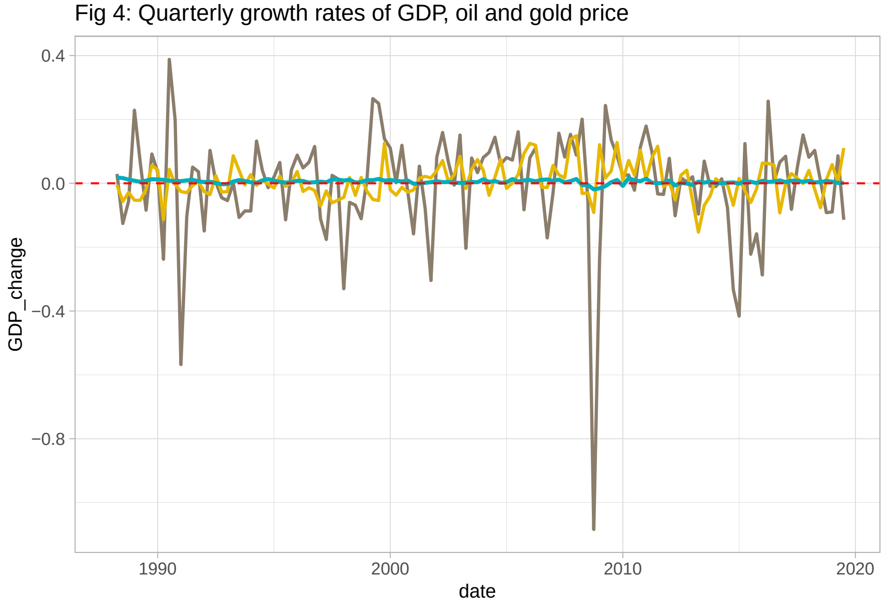

We can see an almost linear upward slope for GDP over time.
Oil prices is fairly stable in the 1990s followed by an exponential growth that ends at its peak in 2008. After a drastic decline in price there is again an upward slope until 2011. Then the price seems again more or less stable until 2014 where another drastic price decline is followed by an upward slope in 2006.
Gold price is also fairly stable in the 1990s and then follows a rather exponential trend until around 2012. After this peak we see a downwards slope until 2016.

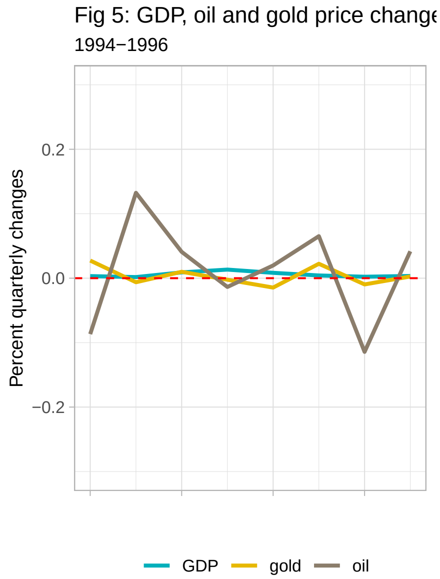
In order to be able to capture non-linearities in the data and to be able to compare GDP and prices which have different value ranges, all three variables are transformed by taking relative differences.

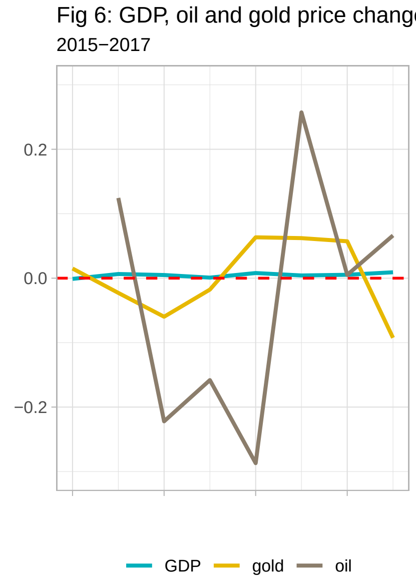
The GDP per capita variable is transformed to quarter-to-quarter growth rates; also commodity prices are transformed into percentage change from the previous time period.

This transformation is possible because there is a natural base for comparison: here the value of the variable in the previous time period .

Fig 4: Quarterly growth rates of GDP, oil and gold price






As expected, GDP is rather stable across the entire timeline.

There is fluctuations in both gold and oil price changes, however the spikes in oil price changes are more extreme than those for gold.

## Analysis

I am going to estimate a time series regression with change in oil price as the dependent variable and change in GDP as the explanatory variable.

*Table 3: Regression summary of oil price change on GPD change*

| | (1) linear regression | |
|---|---|---|
| (Intercept) | -0.05 | (0.04), [-0.13, 0.03] |
| GDP_change | 9.21 | (6.27), [-3.19, 21.61] |
| N | 126 | |
| R2 | 0.10 | |

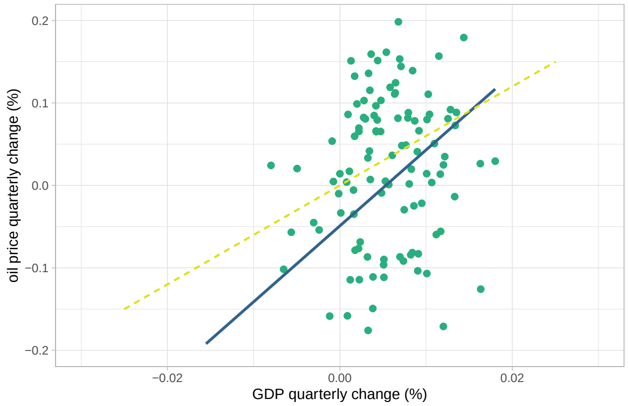
All continuous predictors are mean-centered and scaled by 1 standard deviation. Standard errors are heteroskedasticity robust. *** p < 0.001; ** p < 0.01; * p < 0.05.

If GDP ist stable (0% change) we expect a quarterly oil price change of -0.05%. If GDP changes from one quarter to the next by one percent we expect the oil price to increase by 9.16% (-0.05 + 9.21%).

The model was calculated using the robust standard error, which is correct both under heteroskedasticiy and homoskedasticity while the simple standard errror is correct only under homoskedasticity. The robust standard error produces a larger confidcent interval than using the simple standard error. As a consequence, and probably due to the fact that many other things matter for changes in oil price (large residual standard deviation), we see a relatively wide confidence interval for the slope coefficient. As the conficence intervals inlcude zero in both the intercept and the GDP_change coefficient, we cannot reject the null that that the beta coefficient is zero, which means that the data does not suggest that a change in GDP and a change in oil price are correlated.

Looking at R-squared, only 10% of the variation in oil price changes are explained by the model.

Fig 7: Association between oil price and GDP quarterly changes




As the effect of one variable on another in time series may be delayed, it is often useful to consider including lags. In the following model I am going to add two lags to evaluate the expected change taking into account the change of oil price at a given point in time, but also the previous quarter and the quarter before that.

| | (2) multiple linear regression including lags | |
|---|---|---|
| (Intercept) | -0.06 | (0.05), [-0.16, 0.04] |
| GDP_change | 9.23 | (6.54), [-3.72, 22.18] |
| GDP_change_lag1 | 1.95 | (2.78), [-3.55, 7.45] |
| GDP_change_lag2 | 0.08 | (3.22), [-6.30, 6.46] |
| N | 124 | |
| R2 | 0.11 | |

All continuous predictors are mean-centered and scaled by 1 standard deviation. Standard errors are heteroskedasticity robust. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

In this model two lags are included: the previous quarter, and the quarter before that. The slope coefficients suggest that the more time passes the less impact we can expect from change in GDP on change in oil price. However since all slope coefficients are in each other's confidence interval and contain zero we cannot make a confident statement about whether a change in GDP in the current or one of the previous two quarters is correlated with a change in oil price whatsoever.

Next, I am going to estimate the same time series regression with change in gold price as the dependent variable and change in GDP as the explanatory variable, followed by a multiple regression with two lags.

*Table 4: Regression summary of gold price change on GPD change:*

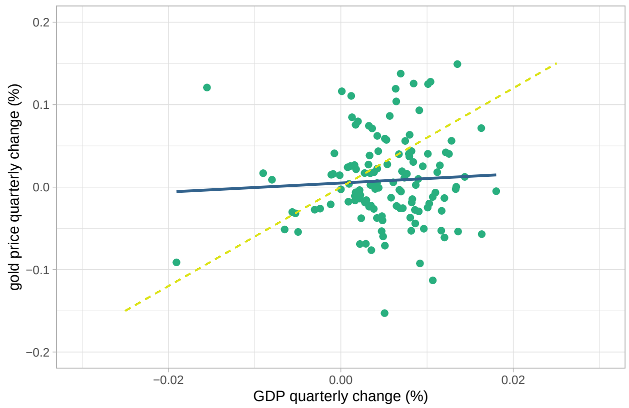
| | (3) linear regression | |
|---|---|---|
| (Intercept) | 0.00 | (0.01), [-0.01, 0.02] |
| GDP_change | 0.55 | (1.13), [-1.69, 2.79] |
| N | 126 | |
| R2 | 0.00 | |

All continuous predictors are mean-centered and scaled by 1 standard deviation. Standard errors are heteroskedasticity robust. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

From the above summary table we can conclude, if GDP ist stable (0% change) we also expect gold price to be stable (0% change). If GDP changes from one quarter to the next by one percent we expect the gold price to increase by 0.55%.

The confidence intervals inlcude zero in both cases, therefor we can't rule out with 95% confidence that the average changes in GDP and change in gold price are the same.

Fig 8: Association between gold price and GDP quarterly changes




In the following model I have included two lags: for the previous quarter and the quarter before that.

| | (4) multiple linear regression including lags | |
|---|---|---|
| (Intercept) | 0.01 | (0.01), [-0.01, 0.03] |
| GDP_change | 1.41 | (1.15), [-0.87, 3.70] |
| GDP_change_lag1 | -1.23 | (1.22), [-3.64, 1.18] |
| GDP_change_lag2 | -0.06 | (1.07), [-2.16, 2.05] |
| N | 124 | |
| R2 | 0.02 | |

All continuous predictors are mean-centered and scaled by 1 standard deviation. Standard errors are heteroskedasticity robust. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

The slope coefficients changes for each lag, however since all slope coefficients are in each other's confidence interval and contain zero we cannot reject the null that beta is zero, meaning we cannot be confident that there is correlation between oil price changes and previous GDP price changes.