Applied Times Series Analysis
Prof. Robert Kunst
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Estimating The US Phillips Curve

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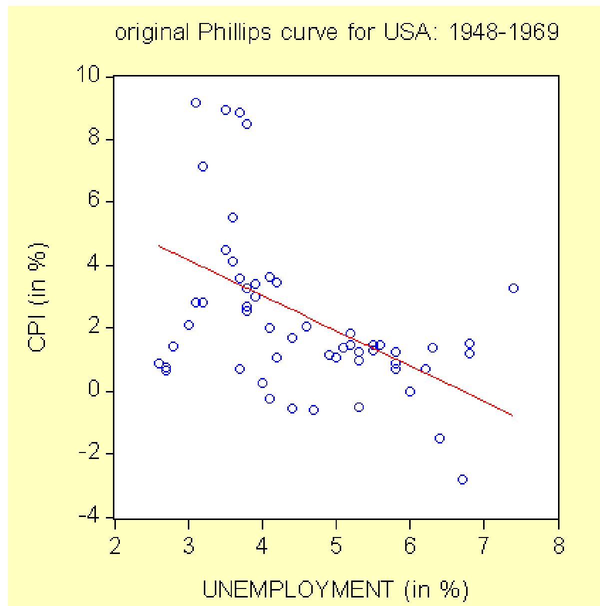
Introduction

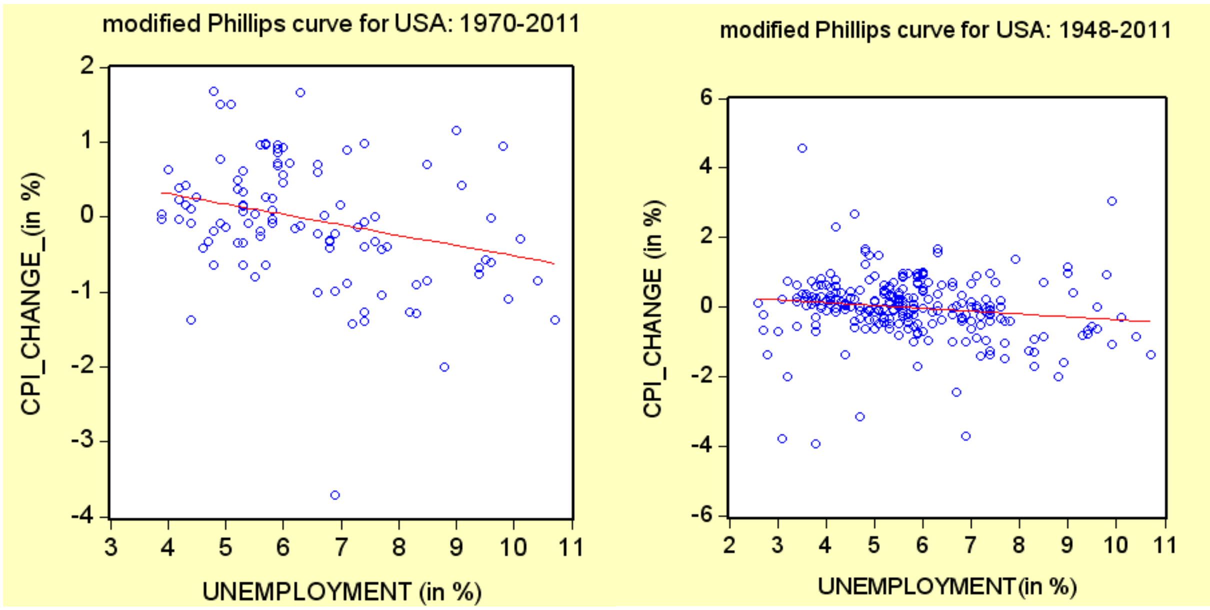
During our search for a topic for this seminar paper for the course Applied Time Series Analysis, we quickly agreed that we wanted to do a vector auto regression (VAR), because we found the possibility of creating a model by ourselves most interesting. While discussing possible input variables, we remembered the Phillips curve and we wanted to build our model around its input variables *inflation* and *unemployment*.
Since the interest rate has a multilateral influence on many macroeconomic variables, we want to test, whether there is also a determining relation with the Phillips curve variables, especially the unemployment rate. This could be analyzed by the means of a vector autoregression model which is based on the variables of the Phillips curve – inflation and the unemployment rate but enlarged with interest rate as exogenous variable.

The Phillips Curve

The Phillips Curve was developed in 1958 by the British Economist Alban William Phillips. During his search for explanatory factors for the level of nominal wages, he plotted the money wage changes and the unemployment rate for the British economy based on a yearly data time series with nearly 100 observations and observed an inverse relationship between the two variables. Two years later Paul Samuelson and Robert Solow based on Phillip's discoveries repeated the study for the USA with inflation rate and unemployment rate and showed a specific, negative relation between the two variables. In times of high inflation a low unemployment rate was perceived and vice versa with high unemployment rate and low inflation. They named the coherence after its original discoverer A.W. Philipps.

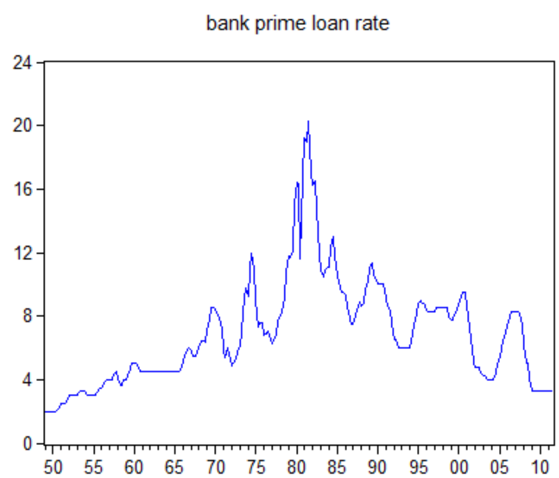


The Phillips curve became a popular element of macroeconomic theories soon after and had great influence on the government policy of the 1960s. Because it was regarded as an instrument for economic policy, the government thought they could achieve low unemployment as long as they were willing to tolerate higher inflation and attain price stability through tolerating a higher unemployment rate. (Blanchard & Illing, 2009; p.250-51)
However, during the 1970s the inverse relation between inflation and unemployment however broke apart and the most of the OECD member states observed stagflation which means high inflation as well as high unemployment. But although the Phillips curve could not explain stagflation, a new relation between unemployment and inflation was discovered, namely the inverse relation of unemployment and changes in inflation. This relationship was the foundation for the modified Phillips curve and is still valid and applicable for many developed countries. Nowadays the interpretation of the Phillips curve is that high unemployment does not cause low inflation, but rather lower increase of inflation. (Blanchard & Illing, 2009; p. 250-53,258)

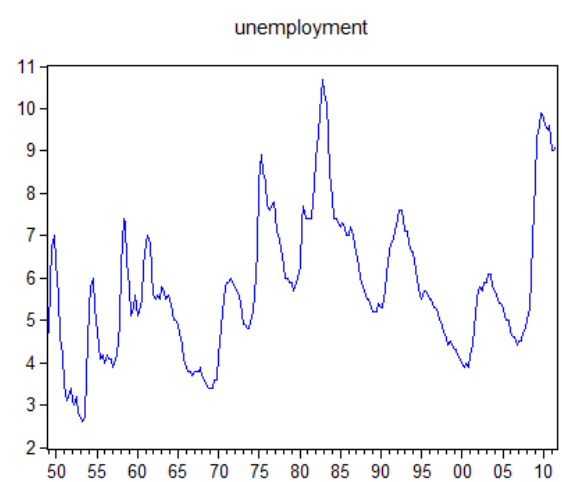


Data

For our model, we consider three time series, namely the “bank prime loan rate”, the unemployment rate and the inflation rate. All of the three series were downloaded from a huge American database hosted by the Federal Reserve Bank of St. Louis called FRED (Federal Reserve Economic Data). In the following, each of the series will be described shortly.

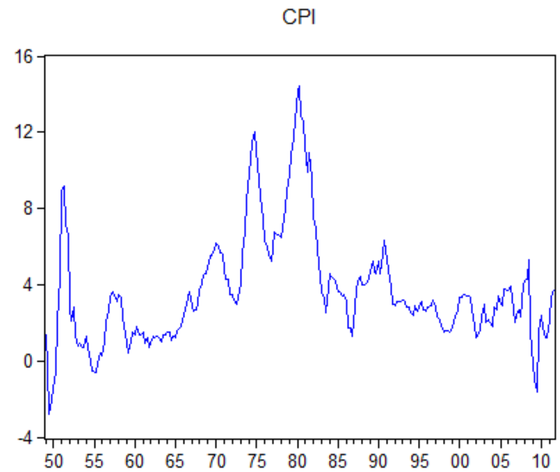


The bank prime loan rate (BPLR):
This series, which is measured in percent, ranges from 1949:01 to 2011:12 and comes initially in monthly distances. It is determined by adding 3 percentage points to the federal funds target rate (comparable to the “Leitzinssatz” issued by the European Central Bank) and serves as an index/base rate for banks and other lending institutions to price short-term business loans. The development reveals rather high values of up to about 20 percent in the early 1980s - reflecting conflicts the US-American economy faced (Oil crisis, e.g.) and the Federal Reserve Bank wanted to counteract with fiscal policy. It is currently at about 3.25 percent. We decided to use quarterly data, whereat for instance for the data point 1966:02 (2nd quarter of '66) the average of



1966:M04 to 1966:M06 is considered as value (when downloading, one can decide about the aggregation method, we chose to take the average).

The unemployment rate (U):
The unemployment rate is defined as ratio of unemployed to the civilian labor force and expressed in percent. It ranges from 2.6 percent in the middle of 1953 to 10.7 percent in 1982. Again, we downloaded quarterly data to work with.



The the inflation rate (CPI):
The inflation rate (derived from the consumer price index) can be downloaded from 1947:01 to 2011:12 and is initially also delivered based on a monthly basis. One can choose several versions of it, we decided to pick the series expressing the inflation as percentage change from the previous year. According to their handbook of methods, the calculation follows:

$$\left(\frac{x(t)}{x(t-4)}-1\right)*100$$

The series reached its maximum at the end of the 1970s (at about 13 to 14 percent). It exhibits negative values (implying deflation) at some points in time and is currently at around 4 percent. In order to have matching series, we also used the quarterly series, again using the average method to compute the quarterly values. Eyeballing already indicates some time-dependent relationship between unemployment and the inflation rate (for example see the beginning of the 1980ies).

Model Estimation

We use a vector autoregressive (VAR) model to investigate the relationship between the nominal interest rate, inflation rate (in short inflation) and the unemployment rate. The most important property of this approach is that we do not need to specify ex-ante which of our variables are endogenous and which are exogenous determined. A three variable VAR model investigates all possible combinations such that each variable is once modeled endogenously (i.e. determined by the other variables) and exogenously (i.e. it is used to model the other ones) in the remaining two specifications.
The first step in order to carry out this approach is to test for stationarity in the three series we use. For the VAR model to be feasible all variables need to be stationary (I(0)) or first difference stationary (I(1)). To test for these properties we carry out augmented Dickey-Fuller (ADF) tests on each of them.
For the inflation rate series we first use an ADF test with an intercept and without a trend component since the series moves well above zero but no long term trend is recognizable. The p-value is 0.1899 and thus we cannot reject the null hypothesis of non-stationarity. On the first differenced inflation rate series we use an ADF test also only with an intercept component since the series does not trend obviously. The p-value then is 0.0000 and thus we reject the non-stationarity null-hypothesis and conclude that the series is I(1). The results and specifications of

the remaining ADF tests can be seen in Table 1:

	ADF specification	p-value
inflation (levels)	intercept, no trend	0.1899
inflation (1st diff.)	intercept, no trend	0.0000
unemployment (levels)	intercept, no trend	0.0026
unemployment (1st diff)	intercept, no trend	0.0000
BPLR (levels)	intercept, no trend	0.1470
BLPR (1st diff)	intercept, no trend	0.0000

Table 1: ADF Test Results

The ADF tests indicate that inflation and the bank prime loan rate are difference stationary (I(1)), whereas the unemployment rate is stationary (I(0)). Since a VAR models requires the included variables to be either I(1) or I(0) we can proceed with this approach. We thus want to estimate the following equation system:

$$X_t = c + \Phi_1 X_{t-1} + \Phi_2 X_{t-2} + \ldots + \Phi_p X_{t-p} + \varepsilon_t$$

Figure 1: VAR Specification

where X_t is a 3x1 vector containing the variables inflation, unemployment and interest rates, c is a 3x1 vector of constants, and the Φ are 3x3 matrices of coefficients. So this system consists of three equations, one for each variable. Since the lag-length p is not derived from theory we need to determine it by comparing different specifications. As a benchmark we use various information criteria. The Schwarz information criterion (SIC) as well as the Hannan-Quinn information criterion (HQC) indicate a lag structure of p = 2. However the Akaike information criterion (AIC) and the final prediction error (FPE) indicate a structure of p = 10. Since the AIC is not a consistent order-selection criterion and additionally tends to overestimate p and the BIC is a consistent information criterion we chose our lag structure based on the BIC (see Brockwell and Davis (2002) p. 173). Therefore we are now able to estimate the model. The results are presented in Figure 2.
Before we begin to interpret our model, we want to determine weather there is a cointegration relationship in our model and therefor perform a Johansen Test. Therefore the specification from Figure 1 is transformed into the following form:

$$\Delta X_t = \mu + \Pi X_{t-1} + \Psi_1 \Delta X_{t-1} + \ldots + \Psi_{p-1} \Delta X_{t-p+1} + \varepsilon_t$$

Figure 2: Cointegration Test Specification

Again X_t is a 3x1 vector and Π and Ψ are 3x3 matrices. We want to test for the rank of the Π -Matrix since it indicates the cointegration relationship of the involved time series. Eviews reports two different versions of the Johansen Test (Trace and Maximum Eigenvalue) but both yield the same results, namely that the rank of the Π -Matrix is equal to 3, since we reject the null hypothesis of rank = 0, rank = 1 and rank = 2 with p-values reported in Table 2. This means that the Johansen Test indicates that our data vector X_t from Figure 1 only contains stationary variables. This contradicts the results from the ADF tests performed before. However, since the Johansen Test reported in Table 2 uses the information of the three time series jointly, we rely on these results.

	p-values	
	Trace Test	**Max Eigenvalue Test**
rank 0	0.00	0.00
rank 1	0.01	0.03
rank 2	0.03	0.03

Table 2: Cointegration Test Results

Since we now believe in the stationarity of all three time series we turn to the interpretation of the estimation results of the simple VAR model. As stated in the introduction we are especially interested in the factors that causally determine the inflation rate and factors that causally determine the unemployment rate.

The significant coefficients in the inflation equation (column 1, Figure 3) indicate, that past inflation (the lagged variable itself) and past unemployment rates influence the inflation rate. Our model suggests that the interest rate has no significant influence on inflation. We expect past inflation to have a positive and past unemployment to have a negative effect. The positive coefficient on CPI(-1) of 1.294 and the negative coefficient on CPI(-2) of -0.359 seem to be in line with these expectations. We interpret the coefficient on CPI(-2) as some kind of something effect which means that past high inflation rates lead to high inflation rates in the next period but the effect is weakened in the following period due to CPI(-2). So the effect of past inflation is highest in the beginning and then fades out. Also the coefficients on U(-1) of -0.471 and on U(-2) of 0.465 support our hypothesis that there is a negative influence of unemployment on the inflation rate even though it seems to be very limited due to the nearly completely offsetting effect through the second coefficient. As in the case of inflation the coefficient on U(-2) ensures that an unemployment shock fades out of the system over time. In the case of unemployment the results from the VAR estimation suggest that past unemployment rates are the only significant determinants of current unemployment. The interest rate has no significant impact, which we had thought it has. Even more surprising is that the interest rate, according to our model, is determined by past interest rates and the unemployment rate. So it seems that there is a reverse causality between unemployment and interest compared to our à priori expectations.

We check the robustness of our results and also run a second specification of our model where we use the interest rate as an exogenous variable. If we include the one and two period lagged values of our interest rate variable both are insignificant as in our baseline specification. However if we include the current and the one period lagged value, in this case the interest rate becomes a highly significant determinant of unemployment. The latter specification can be justified by the very fast transformation of monetary policy changes into the economy. So we get mixed evidence on the relationship between unemployment and the interest rate and further investigations would be needed to provide a satisfying answer.

Nevertheless in order to get an idea about the impact of exogenous changes of the variables on the long run equilibrium in our baseline specification, we carried out an impulse response analysis, which is presented in the next section.

Sample (adjusted): 1949Q3 2011Q3
Included observations: 249 after adjustments
Standard errors in ( ) & t-statistics in [ ]

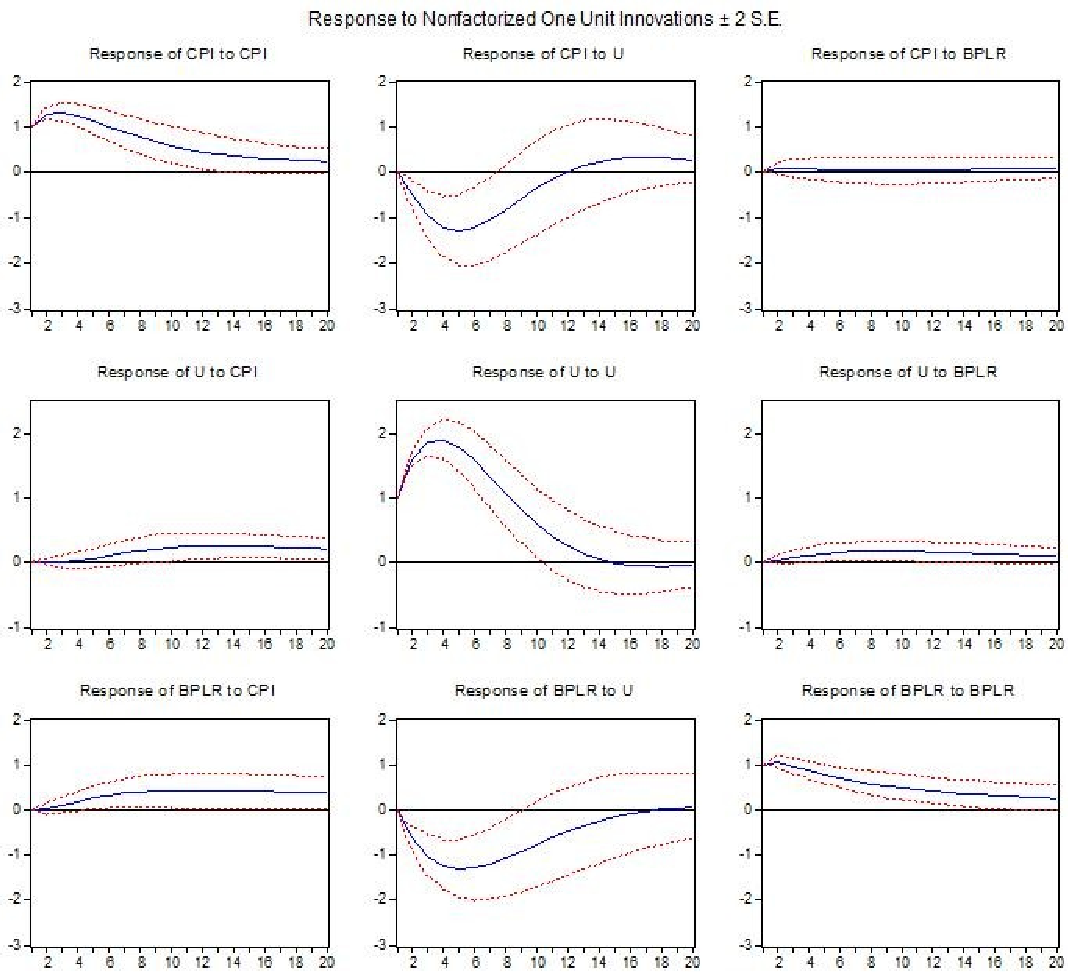
	CPI	U	BPLR
CPI(-1)	1.294159	-0.002133	0.016537
	(0.05969)	(0.02310)	(0.05772)
	[21.6822]	[-0.09234]	[0.28651]
CPI(-2)	-0.359457	0.013434	0.056834
	(0.06104)	(0.02362)	(0.05902)
	[-5.88915]	[0.56867]	[0.96289]
U(-1)	-0.470793	1.588461	-0.602520
	(0.13296)	(0.05146)	(0.12858)
	[-3.54075]	[30.8659]	[-4.68599]
U(-2)	0.465267	-0.643273	0.582884
	(0.13036)	(0.05046)	(0.12606)
	[3.56905]	[-12.7492]	[4.62379]
BPLR(-1)	0.064470	0.041596	1.053491
	(0.06929)	(0.02682)	(0.06701)
	[0.93038]	[1.55092]	[15.7216]
BPLR(-2)	-0.048568	-0.027576	-0.121595
	(0.06870)	(0.02659)	(0.06643)
	[-0.70696]	[-1.03711]	[-1.83032]
C	0.182413	0.179855	0.331741
	(0.18821)	(0.07284)	(0.18200)
	[0.96922]	[2.46904]	[1.82277]
R-squared	0.936542	0.969494	0.955028
Adj. R-squared	0.934969	0.968738	0.953913
Sum sq. resids	136.8331	20.49825	127.9560
S.E. equation	0.751948	0.291039	0.727148
F-statistic	595.2581	1281.832	856.5129
Log likelihood	-278.7787	-42.42506	-270.4278
Akaike AIC	2.295411	0.396988	2.228336
Schwarz SC	2.394295	0.495873	2.327220
Mean dependent	3.679920	5.791566	6.937791
S.D. dependent	2.948674	1.646051	3.387127

Figure 3: VAR Estimation Results

Impulse Response Analysis

Finally, we conducted an Impulse Response Analysis on our estimated VAR – model. Loosely spoken, an Impulse Response Function traces the effect of a one-time shock to current and future values of the endogenous variables. The first line in the figure below shows the “one unit impulse” response of the inflation rate for shocks occurring in one of our three variables. The second row shows the impact of shocks to the unemployment rate and the last row the response of the interest rate we chose.

If we for example take a look at the response of the inflation rate to a one-unit shock in the unemployment rate, we notice that the graph is decreasing for the first five periods. From then on, it increases until period 16, from which on it again decreases.
One can also choose to have this output within a table. It is consistent with the graphical result, since the estimated numbers decrease until we reach the fifth period (-1.286), whereas from this period on, the estimated values increase again. Continuing from period 12 on, these numbers turn out to be positive, again declining as we approach periods 20 and further. This is also in line with the theory about the Phillips curve, which predicts decreasing inflation for an increasing rate of unemployment. For all of these shocks, the figures show, that within the selected time horizon of 20 periods, the variables gradually return to their initial level from before the shock.



Conclusion

The goal of this project paper was to analyze the relation between inflation rate, unemployment rate and the interest rate and check for cointegration. As the analysis of the VAR-model has shown on the previous pages, we had to reject our hypothesis of cointegration between the three variables. Also with focus on interest and unemployment rate, we could not find significant influence of the interest rate on unemployment. However the results of the impulse response give us occasion to think that the interest rate seems to be somehow determined by unemployment rate. Nevertheless the inverse relationship between unemployment and inflation is confirmed by our model, such that higher unemployment decrease inflation.

Literature

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- Federal Reserve Bank of St. Louis, FRED Economic Data [http://research.stlouisfed.org/fred2/14.01.2012,11:50], downloaded January 2012