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THE RELATIONSHIP BETWEEN INFLATION AND UNEMPLOYMENT IN USA

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ABSTRACT

Phillips curve has raised heated discussions in the past few decades since Phillips initially introduced it in 1958. This article examines the Phillips curve's existence and stability using the USA time-series data of inflation and unemployment. First of all, the Phillips curve's status quo will be discussed, along with our motivation to study this. Next, the literature review will be carried out to present the related study of the Phillips curve since the last century, and an explanation will be given as to why the Phillips curve failed to function during the 1970s. Later on, drawing upon the quarterly data from 1980 to 2019, which is derived from the FRED database, the VECM model will be carried out in the empirical part. It is found that the inflation and unemployment were both affected by the lagged values, and they experienced a short-run adjustment as they turned out to diverge from the original points. Simultaneously, these divergences were pulled back by the system to reach an equilibrium in the long-run.

Keywords: Phillips curve; inflation; unemployment; VECM model; USA

INTRODUCTION

Inflation forecasting has given rise to a considerable amount of research in many countries over the past few decades. Scholars managed to find its relationship with the interest rate, monetary policies, commodity prices, and so on (Bikker, 1998; Stock and Watson, 1999; Shahbaz et al., 2012). Besides, it is found that the Phillips curve is one of the most important and popular ways to monitor and estimate the inflation rate. Phillips' (1958) original curve involves a nonlinear relationship between inflation and unemployment. Indeed, the Phillips curve's most common specification either relates the inflation rate to the expected inflation rate and the past period's unemployment level. The other way is to relate this to the output gap, known as the New Keynesian Phillips curve (Walsh, 2010). After the economic crises in the 1970s, Friedman (1968), Okun, Fellner, and Wachter (1975) argued against the Phillips curve relation. They found an unstable relation that there was no long-run co-integration between inflation and unemployment.

Even though the relationship between monetary policy, as measured by inflation or nominal interest rate, and the labor market performance, as measured by unemployment, has been quite an old issue, we would like to take a look at the real business cycle facts (RBC) of the United States from 1957 to 2019. From the business cycle facts, we know that the price level can be procyclical or countercyclical. The unemployment rate is negatively connected with the vacancy rate. We want to focus on the long-run trends of the two variables. To be more specific, in this essay, we would like to test if the relationship which Phillips found still holds overtime. To carry out the study, we would like to analyze the relationship between the inflation rate and the unemployment rate to explore the Phillips curve's existence and examine its nature and stability in the USA's case, both in the short and long run. We derived the quarterly data from 1957 to 2019 to discuss how the relationship goes between the two variables. The data we adopted is derived from the FRED, which provides us with the USA's time-series econometric data. Concerning the methodology, we propose to use a VECM model since we believe that the two nonstationary variables will witness short-run adjustment dynamics. Still, they will converge to a long-run relationship.

In general, we would first conduct the literature review to provide a theoretical basis for our essay. Next, we would like to describe our database as well as the methodology. We would perform the empirical analysis using Eviews11, after which we would present the study results. Finally, we would draw conclusions based on the previous parts.

1. LITERATURE REVIEW

The Phillips curve has been a heated discussion ever since it was introduced by Phillips (1958), who discovered the inverse relationship between nominal wages and unemployment rates. Quite of few scholars studied it for the sake of finding the relationship among nominal wages, CPI or inflation rate, and the unemployment rate and analyzed the trade-off among them (Samuelson and Solow, 1960; Gordon, 1971). And it is believed that the trade-off possibility provides policymakers a tool to cope with the macroeconomic disequilibrium.

As is mentioned above, there exists a trade-off among those indicators. More frequently, substantial academic interest had been drawn on the possibility of a trade-off between inflation and unemployment. Solow (1970) and Gordon (1971) presented the "Solow-Gordon confirmation of the Phillips curve" using the US data. Later, DiNardo and Moore (1999) were able to find the Phillips relation by drawing upon the panel data approach to analyze the OECD countries.

Besides, with the further analysis of Phillip's curve going on, it is found that the unemployment rate and inflation rate turned out to reach a long-run equilibrium while allowing for a short-run adjustment. As Gali and Salido (2001) pointed out, the unemployment rate changes explained the variations in inflation in the UK case, while Reichel (2004) applied the co-integration method to US and Japan and discovered this trend. Later, Furuoka (2007) also found a long-run relationship between the two variables using Malaysia's example. In the same year, Schreiber and Wolters (2007) adopted the VAR co-integration approach and were able to identify a long-run relation for

Germany. This result is also proved by Granger and Jeon (2011), who adopted UK, USA, Australia, Turkey data and developed a time series econometric model, while they found that the strength of this result was rather weaker in recent years. A similar time-series approach was also made by Shahbaz et al. (2011). They managed to confirm the Phillips curve's existence and stability using a small open economy—North Cyprus. They eventually found that the Phillips curve existed both in the short run and long run by adopting the ARDL bounds testing and DOLS approaches. All these studies provide central bank opportunities to stabilize the price level and coexist with a low level of the unemployment rate.

Furthermore, the Phillips curve itself has been developed as well with time going by. One of the most famous evolution is the New Keynesian Phillips Curve (NKPC), which states that inflation is a function of the next period's expected inflation rate (Walsh 2010). The NKPC shows that the current inflation is also connected with the output gap, interest rate, and marginal cost. A positive output gap boosts the marginal cost, and firms can figure out the cost of changing prices and perceive the expected inflation using the information (Baştürk et al., 2014).

In the 1970s, the Phillips Curve's relation was broken; in most countries, members of OECD had higher inflation and unemployment at the same time (Blanchard and Enrri, 2011). According to the analysis of aggregate supply and the labor market, we can establish that inflation is a function of expected inflation and the unemployment rate. We can consider the following equation.

$$\pi = \pi^e + (\mu + z) - \alpha u$$

Where, π is the effective inflation, π^e is expected inflation, μ is factors that influence the general level of prices, z is factors that influence wages, such as bargaining between employers and employees, and u is the unemployment rate. Here the relevant relations are:

i. An increase in the expected inflation increases the effective inflation; according to Friedman (1968), if the responsible for determining wages expect higher prices, they will fix a higher nominal wage. The direct effect is a general increase in level prices or effective inflation.
ii. An increase in the factors that determine the general level of prices or wages allows an increase in effective inflation.
iii. Finally, an increase in the unemployment rate allows a decrease in effective inflation. It is important to consider that higher unemployment is diminishing the acquisitive power of the consumers.

Blanchard, Amighini, and Giavazzi (2012) consider that before 1960 the mean inflation in the USA and Great Britain was close to zero during a big time-analyzed by Phillips, Samuelson, and Solow. This means that for the economic agents, the expected inflation during this period is zero - if the previous year the mean inflation was closed to zero, then the actual year could be the same, then, the null value of expected inflation is the reason for finding the inverse relation in the original Phillips curve.

To summarize, the behavior that Phillips, Samuelson, and Solow found is that when the nominal wage is increasing, then the firm decides to increase the price of their products. The general level of prices is rising. Later, the workers demand higher nominal wages the next time, and the firms increase their prices again. This process is known as the spiral of wages and prices.

The main reason for distortion in the original Phillips curve was how consumers and firms create their expectations. An essential fact of the Phillips curve's instability in 1970 was that some countries were affected by the international crises in oil; some firms increased the prices in a high proportion than nominal wages (Blanchard and Enrri, 2011).

Summarizing, before 1970, the economic agents did not take care of the expected inflation due to generally, the inflation was lower and not persistent. However, when inflation was more persistent due to the international crises of oil, firms and consumers changed their patterns of formulating the expectative. They had the rational idea that, if the inflation was higher in the previous year, it is probably that in the next year, the inflation will be higher too.

It is not surprising that in some countries, monetary policy is more effective than fiscal policy. The monetary regime that the central bank implements are relevant to determine the relationship between unemployment and inflation; for example, regimes other than the classical gold standards and gold-dollar standard of Bretton Woods are characterized by high monetary accommodation.

2. DATA AND METHODOLOGY

As mentioned above, we derived our data from the FRED database, which provides us with the USA's economic data. We adopted the quarterly data of CPI (CPI of 1983=100) and unemployment rate from the first quarter of 1980 to the fourth quarter of 2019. To avoid the 1970s, the Phillips curve failed to work during the decade, which has been discussed above. And through the simple calculation in STATA15, "gen infl=d.cpi", we were able to calculate the inflation rate using the CPI. The formula is listed as follows:

$$Inflation_t = \frac{CPI_{t+1} - CPI_t}{CPI_t} \; t=1,2,3...n$$

we intend to use the VECM model considering that the variables about inflation and unemployment are integrated by order d[1]. And more importantly, as we have discussed in the literature review, theoretically, the inflation and unemployment rate will converge in the long run, and VECM precisely allows variables to experience a short-run adjustment and converge to equilibrium in the long run. The main idea of co-integration is to determine a linear combination of non-stationary variables that will be a stationary process (Enders, 2015). We consider the following equation that represents the equilibrium in the long run:

$$\beta_1 Unemployment_t + \beta_2 Inflation_t = 0 \; t=1,2,3...n$$

To summarize, we would like to consider the following steps: Firstly, Dickey-Fuller Test or KPSS test are applied for determining the stationarity for every variable, second to decide on the number of lags using lag length criteria, and we will plot the AR roots graph to check the accuracy of our chose lags, third the Johansen test for finding the number of co-integration equations in the VECM model and at the same time we would use Wald test for the short-run causality running from unemployment to inflation. Finally, we intend to evaluate the stability and noise white of residuals.

3. EMPIRICAL ANALYSIS AND RESULTS

3.1 Test for Stationarity

Here we conduct the KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test for inflation.

Null hypothesis: inflation is stationary

Table 1. Results for KPSS test

Level test LM-Stat.		
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.177305
Asymptotic critical values*	1% level	0.739
	5% level	0.463
	10% level	0.347

The KPSS test shows whether a time series is stationary or not. According to our results, we have LM statistics and critical values. If the LM statistics are higher than the critical values, then the null hypothesis is rejected, which means inflation is non-stationary.

An important disadvantage in the KPSS test is that it has a high rate of Type I error -it tends to reject the null hypothesis too often-; for this reason, we combine the results with Augmented Dickey-

[1] In this step we need to analyze the stationarity of every variable by Dickey-Fuller Test.

Fuller Test. Then we conduct the ADF test for the unemployment where the null hypothesis is that the series is non-stationary.

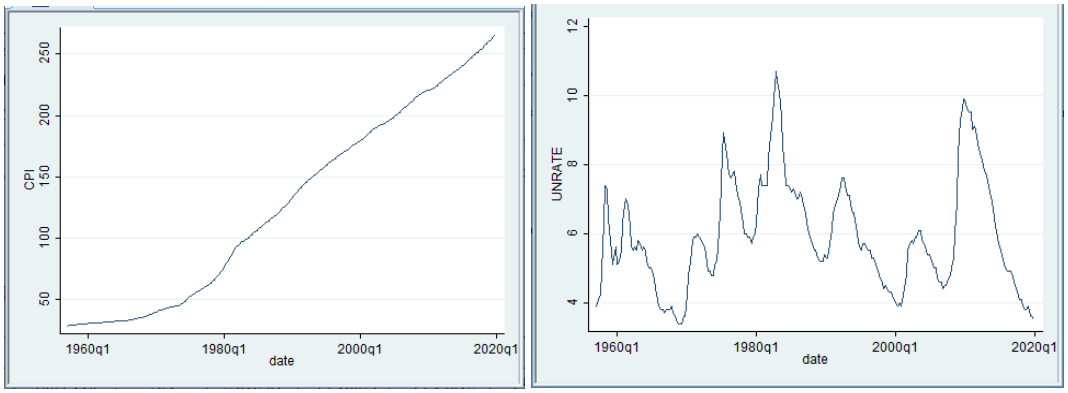
Table 2. Results for ADF test

Level test		t-statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.854304	0.0532
Test critical values	1% level	-3.472259	
	5% level	-2.879846	
	10% level	-2.576610	

Thus, we accept the null hypothesis that unemployment is non-stationary; we reject the null hypothesis from the first-order difference. We conclude that unemployment is non-stationary; however, it is stationary in the first difference.

To summarize, the unemployment rate and inflation are non-stationary in the original values; however, they are stationary in the first difference. It is possible to apply a co-integration between them. Now, we present the series graph of the variables:

Figure 1. Graphs of the two variables



3.2 Lag Length selection

Then we will use AR lag order selection criteria to determine the optimal lags.

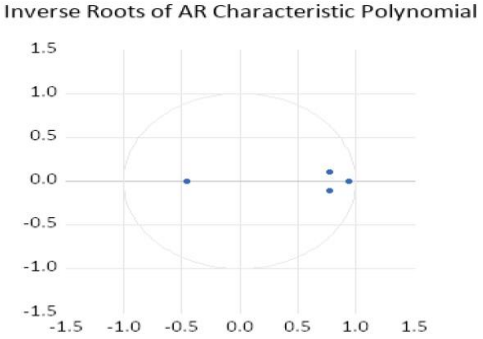
Table 3. AR lag order selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1064.990	NA	2.89e-09	-13.98671	-14.94692	-13.97055
1	1406.000	668.5580	3.43e-11	-18.42105	-18.30168	-18.37256
2	1466.087	116.2218	1.64e-11	-19.15904	-18.96010	-19.07822
3	1485.605	36.47544	1.34e-11	-19.35796	-19.07945*	-19.24482*

* indicates lag order selected by the criterion.

Here according to Schwarz information criterion, we choose to select the 3 lags.

Figure 2. AR roots graph



Then we run the AR roots graph (see figure 2). As the AR roots graph shows, our lag length criterion is feasible. We can conclude that the model is stable.

The following step is to develop the Johansen Test to determine the number of integration equations; in fact, we find one co-integration equation. Now, we present the results for Johansen Test:

Table 4. Johansen Test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.182235	41.42198	25.87211	0.0003
At most 1	0.062319	10.03787	12.51798	0.1255

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Furthermore, it is useful to present the Johansen normalization for determining the impact in the long run of the variables; we show the following results:

Table 5. Johansen normalization results

Normalized cointegrating coefficients (standard error in parentheses):	
Inflation	Unemployment
1.000	-0.045387
	(0.03596)
Adjustment coefficients (standard error in parentheses):	
D(Inflation)	-0.233774
	(0.07223)
D(Unemployment)	0.237851
	(0.05490)

We are assuming that inflation is the dependent variable; if we solve the ratio between -0.0454 and 0.036, we have a value of 10.34%. This means that considering a significance level of 5%, we can not conclude that unemployment has a negative impact on inflation in the long run.

3.3 VECM model

Here we will run our VECM model estimation:

Table 6. VECM model

Vector Error Correction Estimates	
Sample (adjusted): 1981Q1 2019Q4	
Included observations: 156 after adjustment	
Standard errors in ()	
Cointegrating Eq:	**CointEq1**
Inflation(-1)	1
Unemployment(-1)	-0.052955
	(0.03684)
Trend(80Q1)	0.0000482***
	(0.0000013)
C	-0.008237
***p-value<0,01 ** p-value<0,05 *p-value<0,1	

According to the previous table, we can consider that the Cointegration equation (long-run model) is:

$$ect_{t-1} = 1.000000 inflation_{t-1} - 0.052955 unemployment_{t-1} - 0.008237$$

In the following table, we present the results of the VECM model in detail:

Table 7. VECM in detail

Error Correction	D(Inflation)	D(Unemployment)
CointEq1	-0,212471***	0,225711***
	(0,05612)	(0,05329)
D(Inflation(-1))	-0,392507***	-0,012857
	(0,08493)	(0,08768)
D(Inflation(-2))	-0,250838***	-0,020256
	(0,07807)	(0,08060)
D(Inflation(-3))	0,103841	-0,010540
	(0,06682)	(0,06898)
D(Unemployment(-1))	-0,211763***	0,550111***
	(0,07680)	(0,007929)
D(Unemployment(-2))	0,008976	0,262617***
	(0,08858)	(0,09144)
D(Unemployment(-3))	-0,019089	-0,091888
	(0,07589)	(0,07834)
C	-0,000269	-0,0000564
	(0,00017)	(0,00017)

*** p-value<0,01 ** p-value < 0,05 * p-value < 0,10

According to the previous table, we can derive that the estimated VECM with inflation as target variable is:

$$\begin{aligned}\Delta inflation_t = &-0.21245 ect_{t-1} - 0.392507 \Delta inflation_{t-1} - 0.250838 \Delta inflation_{t-2} \\ &+ 0.103841 \Delta inflation_{t-3} - 0.211763 \Delta unemployment_{t-1} \\ &+ 0.008976 \Delta unemployment_{t-2} - 0.019089 \Delta unemployment_{\ t-3} - 0.000269\end{aligned}$$

For the long-run equilibrium, we can see that in both columns, the value is statistically significant at 1% level; this means that for both cases, the previous quarter's deviation from the long-run equilibrium is corrected at a speed of 21% approximately.

Furthermore, we conclude that a percentage change in previous inflation is associated with a 0.3925 percent decrease in the current inflation on average, ceteris paribus in the short run. Similarly, a percentage change in inflation two quarters ago is associated with a 0.2508 percent decrease in current inflation on average, ceteris paribus in the short run. This finding is relevant because we can confirm the effect of expected inflation on current inflation.

Concerning the unemployment rate, we can see that the variables with lags 2 and 3 are not statistically significant; then, we can conclude that these lags' unemployment does not influence current inflation. However, a percentage change in the previous unemployment rate is associated with a 0.2118 percent decrease in current inflation on average, ceteris paribus in the short run. This find is important too because we confirm the relation between unemployment and inflation established by Phillips.

On the other hand, the estimated VECM with unemployment as the target variable is:

$$\begin{aligned}&\Delta[\![unemployment]\!]\_t = \\ &0.225711[\![ect]\!]\_(t-1) - 0.012857\Delta[\![inflation]\!]\_(t-1) + 0.02056\Delta[\![inflation]\!]\_(t-2) - \\ &0.010540\Delta[\![inflation]\!]\_(t-3) + 0.550111\Delta[\![unemployment]\!]\_(t-1) + \\ &0.262617\Delta[\![unemployment]\!]\_(t-2) - 0.091888[\![\Delta unemployment\ ]\!]\_(t-3) - 0.0000564\end{aligned}$$

We can see that the lags of inflation are not statistically significant for the unemployment rate; we can see that the 2 lags of the variable explain the current unemployment. Once again, we have the relevant concept about expectations. We can conclude that a percentage change in unemployment

considering 1 and 2 lags are associated with a 0.55 and 0.26 percent increase in current unemployment. And the speed of adjustment C(1) is not negative either, meaning that there is no long-run causality from inflation to unemployment.

3.4 Long-run cointegration test

In the next table, we present the results of the Least Squares Regression. As we know, C(1) is the speed of adjustment towards equilibrium, and it needs to be negative, meaning that if there is a departure in one direction, the correction would have to be pulled back to the other direction to ensure that the equilibrium is retained.

Here C(1) is negative and statistically significant, which measures the speed at which inflation returns to equilibrium after a change in unemployment. Thus, the long-run equilibrium exists between inflation and unemployment. If we consider a significance level of 5%, we can find the same conclusion by Johansen Test Normalized. The interpretation of C(1) here is that about 21% of departure of long-run equilibrium is corrected at each period.

According to R-squared, we can conclude that the volatility of inflation and unemployment rate considering three lags explain the volatility of current inflation by approximately 43.09%. More precisely, based on F-test, we can find that the model is jointly significant at 1% significance level. However, to conclude that the model has an adequate fit, it is necessary to develop additional tests; they are presented in the following section.

Table 8. Least squares regression results

Dependent Variable: D(INFLATION)
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 05/24/20 Time: 16:18
Sample (adjusted): 1981Q1 2019Q4
Included observations: 156 after adjustments
D(INFLATION) = C(1)*(INFLATION(-1) - 0.0529546411615
UNEMPLOYMENT(-1) + 4.82367807079E-05@TREND(80Q1) -
0.0082365907414) + C(2)*D(INFLATION(-1)) + C(3)*D(INFLATION(-2))
+ C(4)*D(INFLATION(-3)) + C(5)*D(UNEMPLOYMENT(-1)) + C(6)
*D(UNEMPLOYMENT(-2)) + C(7)*D(UNEMPLOYMENT(-3)) + C(8)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.212471	0.051618	-4.116199	0.0001
C(2)	-0.392507	0.084935	-4.621287	0.0000
C(3)	-0.250838	0.078074	-3.212833	0.0016
C(4)	0.103841	0.066822	1.554008	0.1223
C(5)	-0.211763	0.076804	-2.757177	0.0066
C(6)	0.008976	0.088576	0.101339	0.9194
C(7)	-0.019089	0.075889	-0.251543	0.8017
C(8)	-0.000269	0.000166	-1.623027	0.1067

R-squared	0.430913	Mean dependent var	-0.000168
Adjusted R-squared	0.403996	S.D. dependent var	0.002616
S.E. of regression	0.002020	Akaike info criterion	-9.521883
Sum squared resid	0.000604	Schwarz criterion	-9.365481
Log likelihood	750.7069	Hannan-Quinn criter.	-9.458359
F-statistic	16.00935	Durbin-Watson stat	1.913046
Prob(F-statistic)	0.000000		

3.5 Short-run causality

We use the Wald test here, assume null C(5)= C(6)= C(7)=0, which means there is no short-run causality running from unemployment to inflation.

Table 9. Wald test

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	4.663527	(3, 148)	0.0038
Chi-square	13.99058	3	0.0029

Null Hypothesis: C(5)= C(6)= C(7)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(5)	-0.211763	0.076804
C(6)	0.008976	0.088576
C(7)	-0.019089	0.075889

Restrictions are linear in coefficients.

Here we reject the null hypothesis meaning that there is short-run causality between unemployment and inflation.

3.6 Diagnosis tests

An important test is related to the serial correlation. In the following table, we present the results:

Table 10. Residual test

VEC Residual Serial Correlation LM Tests
Sample: 1981Q1 2020Q1
Included observations: 156

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	7,128350	4	0,1293	1,797894	(4, 290.0)	0,1293
2	4,408145	4	0,3536	1,106610	(4, 290.0)	0,3536
3	2,317103	4	0,0001	6,008908	(4, 290.0)	0,0001

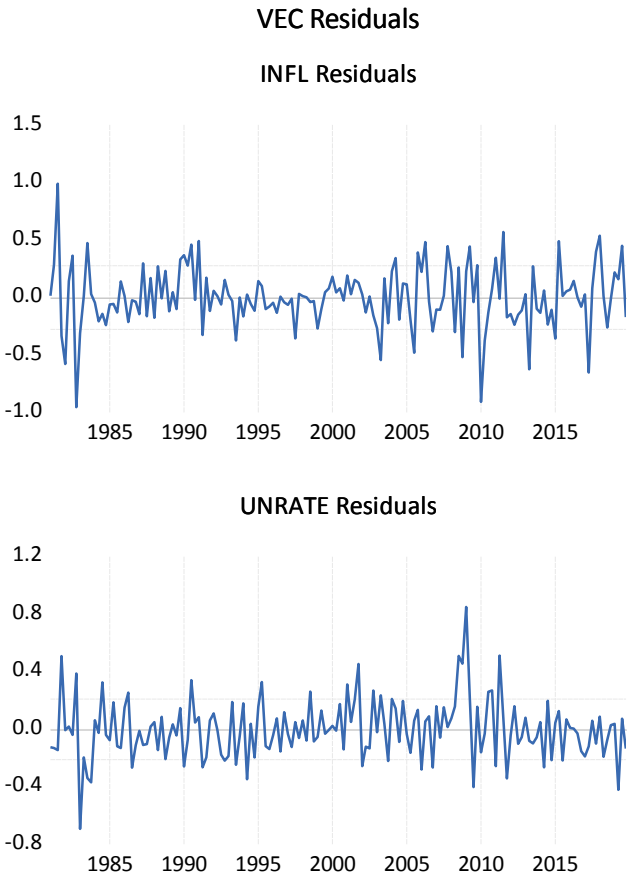
Table 11. Jarque-Bera test

Component	*Jarque-Bera*	*df*	*Prob*
Inflation	2,463751	2	0.0000
Unemployment	2,994206	2	0.0000
Joint	5,457957	4	0.0000

We can see that the model does not present serial correlation at 1 and 2 lags. When we consider 1 or 2 lags, the p-value is higher than 5%. However, at 3 lags, we can suggest that the model residuals are serially correlated. In that case, it is not surprising that in the VECM estimation model, we found that the coefficient in the lag 3 was not statistically significant. Additionally, based on the Jarque-Bera Test, we know that the residuals are not normally distributed (see table 11).

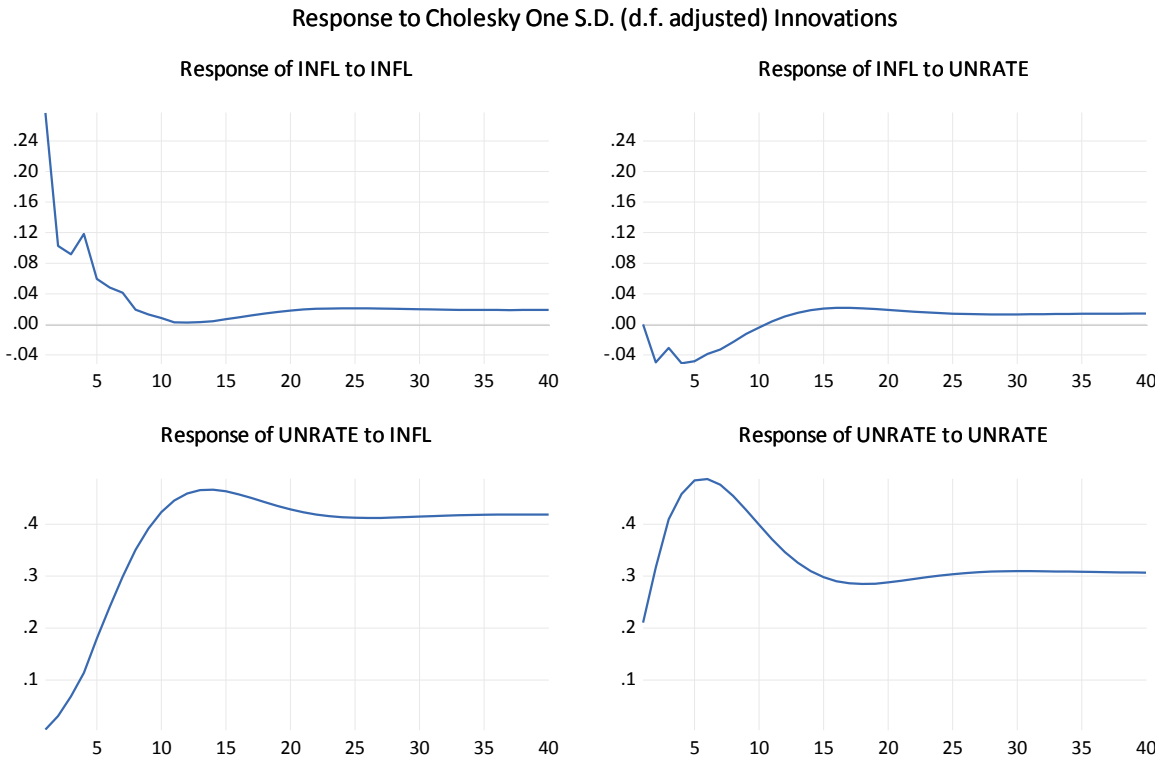
At the same time, we present the graph of the residuals:

Figure 3. VEC Residuals



Finally, we present the graphs of impulse Response Function:

Figure 4. Impulse Response Function.



Impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. And in VECM, we expect that all impulses will die out in the long run.

In the first graph, we can see that the inflation rate is 0.24% at the beginning. The declination in the plot illustrates that, as time passes, the effects of inflation later of 2 years approximately decay to zero. If we compare inflation and unemployment in the second graph, we can see that around in the third year; inflation achieves the stabilization in a value close to zero.

Finally, in the third and fourth graphs we can see that later of 5 and 4 years, respectively the unemployment rate achieves a stable trend, we have a value close to 0.4% in the third graph and close to 0.3% in the fourth graph. Probably, it could be the natural unemployment rate.

CONCLUSION

The Phillips Curve analysis is relevant because it is a useful tool for central banks when they establish monetary policy; we can consider a trade-off between unemployment and inflation rate. In the last decades, a variety of research has been studied to determine the existence of equilibrium in the long run and some relationship between the variables.

According to the literature review, we found that the Phillips Curve's original relation was broken in the 1970s; the main explanation is due to the changes in the behavior of the economic agent's respect to their expectations. Additionally, the international oil crisis made an important distortion between the price level and nominal wages; in summary, the level prices were increasing in a higher proportion than the nominal wages.

According to our model, using a VECM model, we show the existence of equilibrium in the long run by Johansen Test normalized considering at 5% significance level. At the same time, we found that inflation is affected by inflation -considering 2 lags- and unemployment of the previous quarter. Simultaneously, according to the VECM model, we found that the unemployment rate is affected only for the past of this variable, more precisely considering 2 lags. It is an important conclusion related to the expectation of people.

Finally, when it is necessary to analyze the relationship between time series simultaneously, the VAR models are useful. More precisely, when we would like to demonstrate that the series has the same difference order and we know about a stationary equilibrium in the long-run, it is appropriate to use the VECM model.

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