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The Relationship Between Unemployment and Inflation--Evidence From U.S. Economy

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ABSTRACT
In this paper, we apply the Vector Autoregression (VAR) method to check the robustness of Phillips Curve in U.S. economy from Q2 1962 to Q4 2019. Using the cyclical unemployment rate and inflation, the data is described by VAR (4) with a cointegrating rank as 2. To analyse the relation between unemployment rate and inflation, Impulse Response Function (IRF) and Variance Decomposition (VD) are calculated. The results of Granger-causal Test show that the history information of unemployment is helpful for improving the forecasts of inflation. With an increasing forecast horizon, unemployment shocks play an important role on the forecast error variance of inflation. Based on impulse response function, Phillips Curve is still alive in U.S. economy for both long term and short term.
Keywords: *VAR, unemployment, inflation, U.S. economy, impulse response function1*

1. INTRODUCTION

The Phillips curve is an economic concept developed by A. W. Phillips stating that inflation and unemployment have a stable and inverse relationship. The theory claims that with economic growth comes inflation, which in turn should lead to more jobs and less unemployment. However, the original concept has been somewhat disproven empirically due to the occurrence of stagflation in the 1970s, when there were high levels of both inflation and unemployment. Because workers and consumers can adapt their expectations about future inflation rates based on current rates of inflation and unemployment, the inverse relationship between inflation and unemployment could only hold over the short run.

1.1. Related Work

In empirical economy, the Phillips Curve caused many governments to adopt a stop-go strategy where a target rate of inflation was established, and fiscal and monetary policies were used to expand or contract the economy to achieve the target. Hence, many studies exam the robustness of Phillips Curve with different datasets to guarantee the effectiveness of policies.
Although economists broadly support Phillips Curve, it's considered to be inaccurate in some areas and periods. For example, Vera analysed the U.S. economy during two important historical episodes and found the long-run Phillips Curve can be either downward-sloping or upward-sloping.[1]Shaari et.al. investigated the existence of Phillips Curve in high-income countries from 1990 to 2014. [2]

Besides application, researches find that Phillips Curve can be improved by different ways, including adding new factors, improving estimation methods, and changing the linear model. Most research put new factors in to Phillips Curve. For example, Kumar and Orrenius applied wage instead of inflation and found that short-term unemployment has a strong relationship with average and median wage growth.[3] Leightener used bi-directional reiterative truncated least squares to solve the omitted variables problems.[4] Besides, some scholars changed the linear model into nonlinear or non-stationary model. For example, Russell used time series panel data technique that account for the inflation's non-stationarity shifts in mean.[5, 6] Xu et.al. also took U.S. as example and found that inflation appeared more likely to be nonlinear and asymmetric, and varies considerably across quantiles.[7] Also, using different estimation methods is also a common improvement for Phillips Curve. Kajuth applied GARCH as an alternative to GMM estimations to address the simultaneity problems in Phillips Curve.[8] Bildirici and Turkmen analysed the Phillips Curve by using Markov Switching-VAR and Markov Switching Causality Tests.[9]

1.2. Our Contribution

Although previous studies have analysed the correlation between unemployment and inflation, but most have paid attention to the short-term relationship and few studies have addressed the long-term. Motivated by previous theories and practical cases, we aim to find out the robustness of Phillips Curve in U.S. economy from Q2. 1962 to Q4. 2019 in this paper. The reason why we are interested in this period is that the belief of Phillips Curve began in the 1960s where any fiscal stimulus would

increase aggregate demand in U.S. and initiate the following effects.
In this paper, the Vector Autoregression (VAR) model is used to analyse the relation between unemployment rate and inflation. Impulse-Response Function (IRF) and Variance Decomposition (VD) are calculated. The hypotheses we try to test are: 1) whether Phillips Curve is still alive in U.S. for a long term. 2) whether there exists a causal link between inflation and unemployment 3) whether Phillips Curve is useful for economic forecasting.

1.3. Paper Structure

This paper is organized as follows. Section 2 presents the model and methodology. Section 3 contains the empirical results. Section 4 shows the discussion. Section 5 makes conclusions and future extension.

2. METHODOLOGY

2.1. VAR

In this section, VAR model, proposed by Sims (1980), is used. Vector Autoregressive Model (VAR) is a linear model which can capture the rich dynamics in multiple time series. As the VAR model is easily implemented and interpreted, it has long been a standard part of econometrician's toolkit. At present, most of the literature on monetary policy shocks use VAR model.
For a set of Ktime series variables$y_t = (y_{1t}, \dots, y_{Kt})'$, a VAR model captures their dynamic interactions. The basic model of order p (VAR(p)) has the form

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \quad (1)$$

where the A's are$(K \times K)$ coefficient matrices and$u_t = (u_{1t}, \dots, u_{Kt})'$ is an unobservable error term. It is usually assumed to be a zero-mean independent white noise process with time-invariant, positive definite covariance matrix $E(u_t u_t{}') = \sum_u$. In other words, the u_t are independent stochastic vectors with$u_t = (0, \dots, \sum_u)'$.

2.2 Phillips Curve

The Phillips curve states that inflation and unemployment have an inverse relationship. Higher inflation is associated with lower unemployment and vice versa. Understanding the Phillips curve in light of consumer and worker expectations, shows that the relationship between inflation and unemployment may not hold in the long run, or even potentially in the short run.
Hence, a system will be considered with two variables: cyclical unemployment rate and inflation. Because a log-linear relationship has been advised, according to the quantity theory, two-dimensional system (UNEMt, INFt) is employed. It is worth noting that U.S. unemployment data and inflation data can only be provided on a monthly basis. Therefore, we use seasonally adjusted monthly data. The sample period is from Q1 1962 to Q1 2020. All data come from Federal Reserve Economic Data. All the numerical computations are run in Eviews (Version 11).

3. EMPIRICAL APPLICATION

3.1. Unit Root Test

The unit root is investigated at first and the results are shown in Table 1. Only inflation data passed both test before the difference was made, at 5% significance level. After we making the difference, the P-Value of unemployment in PP test is 0, and that of inflation in PP test is 0.0001. The P-Value of unemployment and inflation in ADF test are both 0. According to the appropriate result from both Phillips-Perron Test and Augmented Dicky-Fuller Test, it is the plunk for the result that the data can be treated as I (1).

3.2. Model Specification

Johansen-Juselius cointegration tests are performed on the two-dimensional system. Before the test, the deterministic terms and the number of lagged differences in the model have to be decided. We leave it open whether the trend is just in the variables and, hence, orthogonal to the cointegration relations or whether a fully general linear trend is required. To avoid a decision on this issue at this point, both types of tests are performed.

Table 1 Unit Root Test

Variable	T-Statistic	P-Value	Variable	T-Statistic	P-Value
Augmented Dickey-Fuller (ADF) Test			Phillips-Perron (PP) Test		
unem	-3.105906	0.0274	unem	-2.629140	0.0885
inflation	-9.166047	0.0000	inflation	-9.380340	0.0000
D(unem)	-8.451406	0.0000	D(unem)	-8.495235	0.0000
D(inflation)	-13.51042	0.0000	D(inflation)	-54.43359	0.0001

Another choice that must be made is the number of lagged differences to be included in the models on which the cointegrating rank tests are based. Hence, a new choice is necessary for each of the systems considered. An easy way to make this choice is to ask the model selection criteria for suggestions. The results of lagged differences are shown in Table 2. Based on AIC, a maximum lag order of

5 was considered while the results of SC and HQ suggest VAR (4) has the best fitness. Since the higher number is the proposal of the AIC criterion and selecting too large an order may imply reductions in power, we considered VAR model of orders 4 was fitted without any cointegration restrictions imposed.

All cointegration test results are given in Table 3. For unemployment and inflation system, there is very strong evidence for two cointegrations with both linear trend and quadratic trends. In total, we regard this piece of evidence can outweigh the evidence in favour of no cointegration. Thus, it is reassuring that the test results for the two-dimensional system point to a cointegrating rank of 2.

The next step in our analysis is then to search for an adequate model for the two-dimensional system of unemployment rate and inflation. On the basis of our cointegration analysis results, we start out from a VAR with cointegrating rank 2 and four lagged differences.

Table 2 Model Specification

Lag	AIC	SC	HQ
0	-12.03408	-12.00428	-12.02206
1	-12.48143	-12.39202	-12.44537
2	-12.59714	-12.44812	-12.53703
3	-12.60293	-12.39430	-12.51878
4	-12.73465	-12.46641*	-12.62646*
5	-12.74076*	-12.41291	-12.60853

Table 3 Johansen-Juselius Cointegration Test

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	2	2	2	2	2
Max-Eig	2	2	2	2	2

3.3. Granger Causality Tests

In this subsection, the Granger Causality test is used. Since the residuals are non-Normal1, the linear restrictions in Granger Causality by LR are tested. Table 4 shows that the result of T1 rejects the null hypothesis while the null hypothesis of T2 is accepted. That means the history information of unemployment is helpful for improving the forecasts of inflation while the past values of inflation play a minor role to the forecast unemployment. Judging from above results, it appears that unemployment is Granger-causal for inflation while inflation is not Granger-causal for unemployment.

3.4. Stability Analysis

The stability test is to analyse whether the shock will disappear when a pulse is imposed on the innovation in the VAR model. If so, the VAR system is stable; otherwise, it is unstable. The estimated results manifest that the absolute value of all characteristic roots of the model is less than 1. This shows that the model is a stable system, which can be further analysed.

Generally, the stability test can be used as a standard to test the rationality of theory. Figure 1 represents all reciprocal roots of the characteristic polynomials are located in the unit circle, indicating that the model based on has good stability, so as to ensure the effectiveness of the next study.

Table 4 Granger Causality Tests

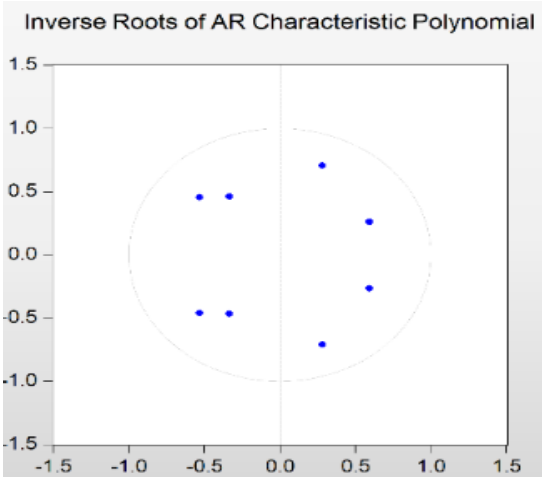
Test1: Dependent variable: D(INF)

Excluded	Chi-sq	df	Prob.
D(UNEM)	1.8913	4	0.7553

Test 2: Dependent variable: D(UNEM)

Excluded	Chi-sq	df	Prob.
D(INF)	20.6743	4	0.0004

H0 of Test 1: Unemployment is not the Granger Cause for Inflation. H0 of Test 2: Inflation is not the Granger Cause for Unemployment.



1 For both Unemployment and inflation, the probability of Jarque-Bera Test is 0, which indicates that both series couldn't satisfy normal distribution.

Figure 1 Stability Test

3.5. Impulse Response

In order to investigate the long-term effect of various variables, we apply impulse response analysis to further explore the relationship between variables. Using Monte Carlo stochastic simulation method, and setting the inspection period as 10 periods, we can get the impulse response function diagram of unemployment rate and inflation.

As can be seen from Figure 2 (a), the unemployment shock decreases inflation immediately, but the decrease dies out within two periods. Finally, the effect of unemployment becomes negative and finally levels out to zero. For unemployment, a positive inflation shock leads to a decrease before period 4 and an increase in a long term (see Figure 2 (b)).

The relationship between unemployment and inflation is slight at longer horizons, which conforms to the long-term Phillips Curve. Also, the positive response of unemployment follows a decline in inflation in this system in a short term. The negative correlation between unemployment and inflation supports the view of Phillips Curve.

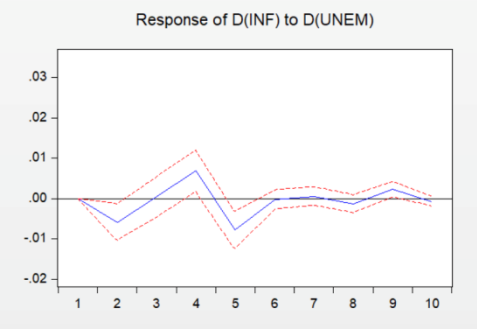


Figure 2 (a)

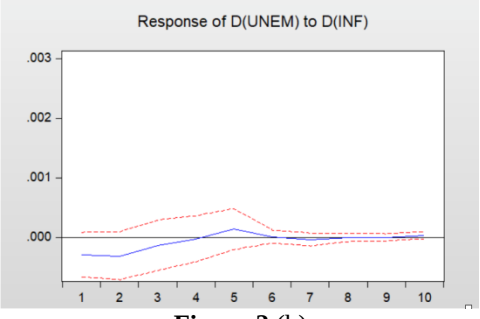


Figure 2 (b)

Figure 2 Impulse Response Function

3.6. Variance Decomposition

To assess the importance of the different shocks for the system variables, the forecast error variances of the variables are decomposed with respect to the shocks. The results for different forecast horizons are presented in Table 5. It turns out that inflation shock contributes a small fraction to the forecast error variance of unemployment. This result proves that the innovation in inflation does not seem to be an accurate indicator for unemployment.

Also, unemployment shocks play a minor role in the forecast error variance of inflation for the short run. However, with an increasing forecast horizon, the unemployment shocks become more and more important and finally level out at 8.6%.

Table 5 Variation Decomposition

Variance Decomposition of D(INF):			Variance Decomposition of D(UNEM):		
Period	D(INF)	D(UNEM)	Period	D(INF)	D(UNEM)
1	100.0000	0.0000	1	1.0561	98.9439
2	97.6734	2.3266	2	1.7240	98.2760
3	97.7758	2.2242	3	1.7076	98.2924
4	94.8766	5.1234	4	1.6374	98.3626
5	91.4898	8.5102	5	1.7810	98.2190
6	91.7383	8.2617	6	1.7819	98.2181
7	91.7243	8.2757	7	1.7950	98.2050
8	91.6892	8.3108	8	1.7948	98.2052
9	91.4067	8.5933	9	1.7939	98.2061
10	91.3803	8.6197	10	1.8012	98.1988

4. DISCUSSION

The results of Granger Test indicate that unemployment is Granger-causal for inflation while inflation is not Granger-causal for unemployment, which demonstrates that the regulation of unemployment contributes to the control of inflation. This conclusion is also substantiated by the results of Variance Decomposition that with an increasing forecast horizon, the unemployment shocks to inflation become increasingly important and finally level out at 8.6%, higher than the influence of the inflations shocks to the unemployment. This result is also verified by Xu, et.al. and Albuquerque and Baumann (2017). [7, 10] The slight relationship between inflation and unemployment indicates that our conclusion conforms to the long-term Phillips Curve, which demonstrates that long-term Phillips Curve is still alive. The result also can be found in researches of Kumar and Orrenius [3] and Zhang and Si [11].

Our results of Impulse Response are consistent with both short-term Phillips Curve and long-term Phillips Curve. Although estimated results don't manifest evident negative

relationship between unemployment and inflation [2], Cumulative Impulse Response shows slightly negative correlation by cumulating response of inflation to unemployment shocks as well as response of unemployment to inflation shocks.

In terms of policy guidance, the regulation of unemployment contributes to the control of inflation. Hence, fiscal policy results in monetary policy while monetary policy couldn't render fiscal policy. Besides, negative relationship between unemployment and inflation, manifested by cumulative impulse response, explains that expansionary fiscal policy contributes to contractionary monetary policy, and it can't be reversed. Contractionary policies can be adopted to exchange high unemployment rate for low inflation, which provides theory basis for choosing economic policies. Hence, short-term and long-term Phillips Curve are both still alive in U.S. economy.

5. CONCLUSION

In this paper, the Vector Autoregression (VAR) model is used to check the robustness of Phillips Curve in U.S. economy from Q2 1962 to Q4 2019. The cyclical unemployment rate and inflation are applied. With a cointegrating rank as 2, VAR(4) was fitted.

There are strong evidences that unemployment is Granger-causal for inflation while inflation is not Granger-causal for unemployment, which means the history information of unemployment is helpful for improving the forecasts of inflation. With an increasing forecast horizon, unemployment shocks play an important role on the forecast error variance of inflation. Based on impulse response function, for short term, the negative correlation between unemployment and inflation supports the view of Phillips Curve; for long term, the relationship between unemployment and inflation is slight at longer horizons, which conforms to the long-term Phillips Curve. Hence, Phillips Curve is still alive in U.S. economy. Any fiscal stimulus would increase aggregate demand in U.S. and initiate the following effects.

Future extensions will include, but not limited to follows. First, GARCH-type volatility can be added into VAR model to improve accuracy. Second, our results can be examined with different monetary systems in different areas. Lastly, VAR model can be improved by changing the normality assumption with Exponential Power Distribution (EPD) or Asymmetric Exponential Power Distribution (AEPD).

Appendix 1 Estimated Results

The model we estimated is

$$y_{1t} = b_0 + b_1\, y_{1,t-1} + b_2\, y_{2,t-1} + b_3\, y_{1,t-2} + b_4\, y_{2,t-2} + b_5\, y_{1,t-3} + b_6\, y_{2,t-3} + b_7\, y_{1,t-4} + b_8\, y_{2,t-4} + e_{1t} \quad (2)$$

$$y_{2t} = \beta_0 + \beta_1\, y_{1,t-1} + \beta_2\, y_{2,t-1} + \beta_3\, y_{1,t-2} + \beta_4\, y_{2,t-2} + \beta_5\, y_{1,t-3} + \beta_6\, y_{2,t-3} + \beta_7\, y_{1,t-4} + \beta_8\, y_{2,t-4} + e_{2t} \quad (3)$$

where y_1 means unemployment rate, and y_2 means inflation. Table 6 shows the estimated results.

Table 6 Estimated Results

	unem				inflation		
b0	0.0000			β0	0.0001		
b1	0.5282	b5	0.0181	β1	-2.0387	β5	2.0605
b2	-0.0046	b6	0.0007	β2	-0.5214	β6	-0.3146
b3	0.0849	b7	-0.0924	β3	0.1739	β7	-2.6089
b4	-0.0007	b8	0.0047	β4	-0.5391	β8	-0.2931

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[2] Based on the negative relationship, b2, b4, b6, b8, β1, β3, β5, β7 are all supposed to be negative. However, according to estimated results, b2, b4, β1 and β7 are negative while b6, b8, β3 and β5 are positive.

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