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The Business Cycle, Inflation, and Unemployment Rate Nexus: An Empirical Approach

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Abstract

This paper revisits the main assumption regarding the original Phillips curve regarding the American economy, in which one assumes that the unemployment rate causes an inflation rate. In this context, this paper aims to evaluate if the variance of the inflation rate affects the unemployment rate and, besides, if there is a one-way causality from the variance of the inflation rate to the unemployment rate. Based on quarterly time series from 1959:04 to 2019:04 the empirical results show, via OLS and GMM methods, that the monetary policy affects the business cycle, and, in turn, the business cycle impacts the unemployment rate. Hence, the monetary policy affects indirectly the unemployment rate via the business cycle. On the other hand, the variance of the inflation rate contributes to an increase in the unemployment rate, consequently, there isn't a trade-off between the unemployment rate and the variance of the inflation rate. Moreover, there is a one-way causality from the variance of the inflation rate to the unemployment rate. This is the contribution of this paper. At last, based on the Phillips curve, one expects that the unemployment rate causes the inflation rate. However, the Granger causality tests display a two-way causality relation between both variables.

Keywords: Phillips's curve, variance of inflation rate, unemployment rate, Granger causality, business cycle

1. Introduction

Phillips (1958) showed that there is a negative correlation between the unemployment rate and the rate of change in money wage rates from 1861 and 1957 in the United Kingdom. Considering that the inflation rate and variation of nominal wages tend to move together, Samuelson and Solow (1960) confirmed the negative correlation between the unemployment rate and inflation rate in the US. According to them, this correlation emerged because low unemployment rates are associated with high aggregate demand that, in turn, contributes to increasing the wage as well as all the prices of the economy.

Friedman (1968) highlights that there is always a temporary trade-off between inflation and unemployment, although there isn't a permanent trade-off in the long term. Hence, he highlights that the temporary trade-off is not explained by the inflation itself, but by the non-expected inflation, which generally generates an increase in the inflation rate.

Despite this, there have been several modifications in the Phillips curve, since the hypothesis of the natural unemployment rate (Lucas, 1972a; Phelps, 1995) passing by the rational expectation theory (Muth, 1961; Lucas, 1972b; Sargent, 1973; Barro, 1976, 1977), among other relevant modifications, the trade-off between inflation and unemployment is still generally accepted.

However, a correlation between two variables does not mean causality and, in this sense, the relation of causality

can result in three possible results: there is no causality, there is two way-causality, and there is a one-way causality. The empirical models on the Phillips curve implicitly assume that there is a one-way causality from the unemployment rate to the inflation rate.

Sasongko and Huruta (2018) show that the variation of unemployment rate causes the inflation rate based on Granger causality tests. Since the unemployment rate variable is not stationary, but the inflation rate is, the authors used the unemployment rate in the first difference. This procedure is usual because it is not possible to use variables I(0) and I(1) together. However, this adaptation is different from the original Phillips curve. This is just one example, but there are many in the literature. So what?

The point is that the Phillips curve relates the inflation rate to the unemployment rate instead of the inflation rate to variation in the unemployment rate. The unemployment rate variable is already measured as a proportion of unemployed people. Therefore, when one uses the first difference, the original Phillips curve is not being evaluated anymore, but rather the relationship between the inflation rate and the variation in the unemployment rate. Hence, this study is not the same, and the empirical results would not be the same as well. Such modifications can be accepted as an evolution of the Phillips curve, as well as the evaluation between the variation of the inflation rate and the unemployment rate that took place in the American economy from the 1970s onwards. These changes to the original Phillips Curve started to be called the modified Phillips curve or expectations-Augmented Phillips curve. In this context, McCallum (1982) contextualizes and analyzes some critical issues of macroeconomics based on rational expectations in the 1970s.

It is worth noting that Hooper et al. (2020) show as the US labor market has tightened beyond full employment with relatively little evidence of inflation pressure. Hence, the authors are increasingly inclined to declare the demise of the Phillips curve, since the flattening of its slope to zero. In other words, there is some empirical evidence that there isn't a trade-off between the unemployment rate and the inflation rate.

The first motivation of this paper is to evaluate if there are causal relations between the unemployment rate and the inflation rate, as the original Phillips curve, instead of the followings cases:

i) relation between variation of the inflation rate and unemployment rate.

ii) relation between the inflation rate and variation of unemployment rate.

iii) relation between the variation of the inflation rate and variation of the unemployment rate.

In this context, this paper aims to evaluate at first the causality between the unemployment rate and inflation rate for the US economy based on quarterly data from 1959:04 to 2019:04. In other words, this article is interested in analyzing the main assumption of the original Phillips curve, i.e., if there is a one-way causality in which the unemployment rate causes the inflation rate. Nonetheless, if this assumption is not confirmed based on Granger's causality tests, it could be interesting to evaluate new approaches theoretically or empirically between both variables. As this is the case, one can test the relation between the unemployment rate and the variability of inflation rate based on several empirical models if the Granger causality tests generate a one-way causality. Besides, one can also incorporate the monetary policy based on the variability of the real interest rate in the empirical models. As a result, one can test a new approach between the variance of the inflation rate and the unemployment rate. However, the contribution of this paper is evaluating if the variance of the inflation rate affects the unemployment rate and, besides, if there is a one-way causality from the variance of the inflation rate to the unemployment rate.

The questions that should arise, considering the previous paragraph, should refer to the reason for the use of the variability of inflation rates, as well as of the real interest rate. In this context, from the worker's point of view, given the rigidity of nominal wages, the greater the volatility of the inflation rate is, the greater the variability of real wages will be. In this way, one creates an environment of uncertainty and instability in the job market, which can contribute to the increase in unemployment. In the same vein, from the company's point of view, greater volatility in the real interest rate implies greater uncertainty and instability regarding the decision to invest on productive activities, which contributes to lower demand for workers. In other words, with the greatest uncertainty due to the volatility of the real interest rate, it becomes difficult for the entrepreneur to compare the return rate of his investment project with the real market interest rate. The firm tends to invest when the rate of return on its project is higher than the real interest rate, considering still that the real interest rate will be reasonably predictable and stable in the medium and long term.

2. Method

Table 1 shows the description of the database from the Federal Reserve Bank where the first part (Variable's description 1) displays the time series data and their respective codes and definitions. The second part (Variable's

description 2) exhibits the transformed variables used in the estimations of the unemployment rate and unemployment cycle.

There are three dependent variables in percent. The first one is the unemployment rate. The others show the unemployment cycle; one of them is measured by the difference between the unemployment rate and the natural unemployment rate in long term, while the other is given by the difference between the unemployment rate and the natural unemployment rate in the short term.

The first explanatory variable is a dispersion measure based on the variance of Consumer Price Index rate, i.e., the variance of inflation rate, which is the main variable of interest. The second one is the control variable measured by the difference between the real GDP and the trend from Hodrick and Prescott Filter, which is a proxy for business cycle or output-gap.

Table 1. Database (Quarterly data from 1959:04 to 2019:04)

Variables code from FRED	**Variable's description 1**
LRHUTTTTUSQ156N	Harmonized Unemployment Rate: Total: All Persons for the United States, Percent
NROU	Natural Rate of Unemployment (Long-Term), Percent
NROUST	Natural Rate of Unemployment (Short-Term), Percent
GDPC1	Real Gross Domestic Product, Billions of Chained 2012 Dollars
CPALTT01USQ657N	Consumer Price Index: Total All Items for the United States, Growth Rate Previous Period
BOGZ1FL072052006Q	Interest Rates and Price Indexes; Effective Federal Funds Rate (Percent), Level, Percent
Variables	**Variable's description 2**
Unemployment Rate	Harmonized Unemployment Rate: Total: All Persons for the United States, Percent
Unemployment cycle LT [(3)]	(Unemployment Rate) – (NROU)
Unemployment cycle ST [(3)]	(Unemployment Rate) – (NROUST)
Business cycle [(1)]	(GDPC1 - HP trend)
Inflation rate	CPALTT01USQ657N
Variance of Inflation Rate [(2)]	Variance of CPALTT01USQ657N
Real Interest rate	(BOGZ1FL072052006Q) – (CPALTT01USQ657N)
Variance of real interest rate [(2)]	Variance of (BOGZ1FL072052006Q) –(CPALTT01USQ657N)

Data source: Federal Reserve Bank of St. Louis.

Note. 1): HP_Trend = Hodrick-Prescott Filter. 2): Variance = $\Sigma(Xi - \mu)^2/(n-1)$, where μ = mean and n = number of observations. 3): LT = Long Term and ST = Short term.

Table 2. Descriptive statistics

	Unemployment rate	Unemployment Cycle LT	Unemployment Cycle ST	Business cycle	Variance of inflation rate	Variance of real interest rate
Mean	5.957953	0.454973	0.407689	-1.46E-10	0.002732	0.042883
Median	5.633333	0.172783	0.172783	-6.404194	0.000784	0.015105
Maximum	11.16667	5.394181	5.053778	373.3346	0.058203	0.673616
Minimum	3.200000	-2.626905	-2.626905	-419.3459	2.61E-08	1.40E-06
Std. Dev.	1.640114	1.584930	1.494764	128.8049	0.006164	0.079200

Note. 241 observations.

Table 3. Correlation matrix

	Unemployment rate	Unemployment cycle LT	Unemployment cycle ST	Business cycle	Variance of inflation rate	Variance of real interest rate
Unemployment rate	1	0.948	0.953	-0.538	0.069	0.332
Unemployment cycle LT		1	0.996	-0.551	0.016	0.301
Unemployment cycle ST			1	-0.560	0.017	0.304
Business cycle				1	0.083	-0.060
Variance of inflation rate					1	0.249
Variance of real interest rate						1

Table 2 exhibits the descriptive statistics of the empirical models' variables. It is worth highlighting the statistics from the three dependent variables. Although the mean of unemployment rate is about 6%, the mean of both

unemployment cycles variables ranges between 0.40 and 0.46, because both unemployment cycle variables deduce from the unemployment rate the variables related to unemployment natural of the long term as well as of the short term.

The correlation matrix presented in Table 3, shows that there are no high correlations between the three dependent variables and the explanatory variables. In this way, the problem of multicollinearity is avoided. In addition, each of the three dependent variables shows a positive correlation with the variance of inflation rate. On the other hand, such dependent variables show a negative correlation with the variable business cycle. However, correlation is not causality. In this sense, it is relevant investigating causal relations between the inflation rate and unemployment rate.

Based on Granger (1969), one can test the causality between the dependent variables and the explanatory variables. Tables 1A, 1B and 1C show the Granger causality tests between the dependent variables and the inflation rate. The empirical results display that there are two way-causality relations between the unemployment rate and inflation rate, as well as between the variables of unemployment cycle (long term and short term) and inflation rate. These results are not consistent with the main presuppose of the Phillips curve, i.e., that there is a one-way causality from the unemployment rate to the inflation rate.

However, the Granger causality tests show that the variance of inflation rate causes unemployment rate, as well as causing unemployment cycle of long term and unemployment cycle of short term, as shown in the tables 2A, 2B and 2C. Moreover, the business cycle also causes unemployment rate, and in this same vein, causes unemployment cycle of long term and short term, as shown in the tables 3A, 3B and 3C. Besides, Structural VAR (SVAR) analysis is used in order to display impulse response functions.
Taking into account these first considerations, one can explicit the empirical equations as follows:

$$(Business\ cycle)_t = \alpha o + \alpha_1(Business\ cycle)_{t-1} + \alpha 2(variance\ of\ real\ interest\ rate)t + Z_t \quad (1)$$

$$U_t = \beta_0 + \beta_1 U_{t-1} + \beta_2 U_{t-2} + \ldots . + \beta_n U_{t-n} + \delta_0(Business\ cycle)_t + \delta_1(Variance\ of\ inflation\ rate)t + \varepsilon_t \quad (2)$$

Regarding equation 1, the business cycle responds to variance of real interest rate, where parameter αo is the coefficient of the constant term; α_2 *is* the lag from the dependent variable, and Z_t is the error term. This equation is a simplified version of the IS curve.

Based on equation 2, the dependent variable *Ut* can be unemployment rate, unemployment cycle of long run or unemployment cycle of short run; *t* is the time from *1* to *n*: β_0 is the coefficient of the constant term; β_1, β_2, ... β_n are the coefficient lags from the dependent variables, and ε_t is the error term. It is expected that $\delta_0 < 0$, i.e., higher demand contributes to reducing the unemployment rate. Besides, if one expects a trade-off between the unemployment rate and the variance of inflation rate, so that $\delta_1 < 0$. Nonetheless, one should keep in mind that this new approach is not a new version of the Phillips curve, but it can show a new connection between both variables. In this context, based on the hypothesis inspired by Hayek (2011), in which the persistent increment of the inflation rate, due to monetary expansion, contributes to the increasing unemployment rate, one can expect that the coefficient from the variance of the inflation rate is positive, so that $\delta_1 > 0$.

Hayek (1979) argues that current unemployment is, in the final analysis, a direct and inevitable consequence of full employment policies, although in the short term it generates additional jobs. The policymakers' goal of keeping the economy in full employment, through expansionary economic policies, ends up resulting in misallocation of labor and, consequently, in more unemployment.

The strategy of the empirical approach begins with an empirical model based on ordinary least squares (OLS). After that, one tests the robustness of the empirical results based on other methods. In this context, one uses the robust least squares (RLS) method that refers to a variety of regression methods, which are *robust*, or less sensitive to outliers. There are some methods for RLS to determine a regression model: M-estimation (Huber, 1973), S-estimation (Rousseeuw & Yohai, 1984), and MM-estimation (Yohai, 1987).

Moreira et al. (2016) also estimate a system of two regressions via GMM to avoid endogeneity problems using instrumental variables (IV). In this sense, the IV must be good in order to be relevant and valid. The authors use the test of over-identifying Sargan-Hansen also known as J-statistic. Besides, the Stock-Yogo test (2005) evaluates the null hypothesis, which the instruments are weak, based on the Cragg-Donald test. In this context, see Moreira (2001), Stock and Yogo (2004), or Stock, Wright, and Yogo (2002). Moreover, they use the procedure of Newey and West (1987a, 1987b) for all estimated models to minimize problems of unknown heteroskedasticity, as well as serial correlation of the residuals. Hence, in order to test the empirical results robustness in this article, one follows Moreira et al. (2016), who show in more detail the methodological aspects.

3. Results

Table 4 shows that all the variables are statistically significant at 5% level, and hence all of them are stationary series.

Table 4. Unit root tests (H0: time series has unit root)

	Augmented Dickey-Fuller test statistic (ADF)			Phillips-Perron test statistic (P.P.)		
Variables	Critical value: 5% level	t-Statistic	p-value	Critical value: 5% level	Adj. t-Stat	p-value
Inflation rate	-2.87349	-3.28107	0.0169	-2.873390	-7.51315	<0.001
Variance of inflation rate	-2.87349	-5.04323	<0.001	-2.873390	-10.1967	<0.001
Unemployment Rate	-2.87380	-3.69779	0.0047	-2.873390	-3.18863	0.0219
Unemployment cycle Long Term	-2.87380	-3.77077	0.0037	-2.873390	-3.35197	0.0137
Unemployment cycle Shor Term	-2.87380	-3.79293	0.0034	-2.873390	-3.50197	0.0087
Business cycle	-2.87349	-5.75892	<0.001	-2.873390	-4.88722	<0.001
Variance of real interest rate	-2.87349	-3.19507	0.0215	-2.873390	-7.68247	<0.001

Note. Include Constant.

3.1 Granger Causality Tests and Structural VAR

This subsection shows granger causality tests and structural VAR (SVAR) analysis. Good descriptions of structural VAR can be found in Hamilton (1994) and Stock and Watson (2001), for instance. The SVAR allows deriving the impulse response functions considering a period of three years, i.e., twelve quarters.

Based on the Phillips curve, one expects that unemployment rate causes inflation rate. However, the Granger causality tests display a two-way causality relation between them according to Table 1A. Figure 1 shows impulse response functions between both variables with 11 lags. Tables 1B and 1C also show a two-way causality between the inflation rate and unemployment cycle in the long term, as well as between inflation rate and unemployment cycle in the short term. Figures 1B and 1C also show impulse response functions with 11 lags.

Table 1A. Granger causality tests (inflation rate & unemployment rate)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation rate does not granger cause unemployment rate	235	3.79960	0.0013
Unemployment rate does not granger cause inflation rate		2.69904	0.0150
6 lags order selected by the SC criterion			
Null hypothesis:	obs.	f-statistic	prob.
Inflation rate does not granger cause unemployment rate	234	3.41382	0.0017
Unemployment rate does not granger cause inflation rate		3.74353	0.0007
7 lags order selected by the HQ criterion			
Null hypothesis:	obs.	f-statistic	prob.
Inflation rate does not granger cause unemployment rate	230	2.14858	0.0185
Unemployment rate does not granger cause inflation rate		3.15021	0.0006
11 lags order selected by the LR, FPE and AIC criterions			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion. 2) Quarterly data from 1959:04 to 2019:04.

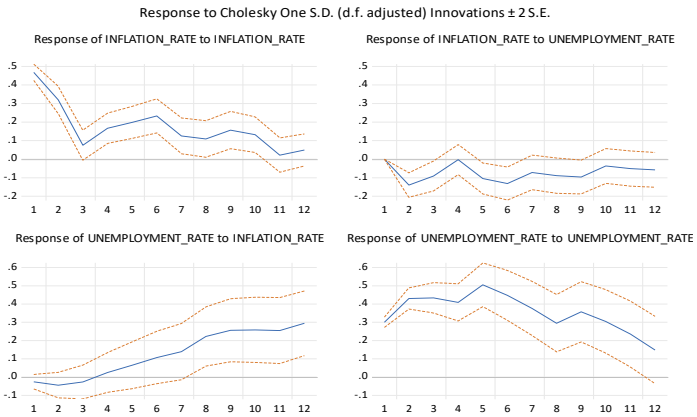

Figure 1A. SVAR analysis: inflation rate and unemployment rate

Table 1B. Granger causality tests (inflation rate & unemployment cycle long term)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation Rate does not Granger Cause Unemployment Cycle LT	235	2.97206	0.0082
Unemployment Cycle LT does not Granger Cause Inflation Rate		3.14263	0.0056
6 lags order selected by the SC criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation Rate does not Granger Cause Unemployment Cycle LT	234	2.63072	0.0125
Unemployment Cycle LT does not Granger Cause Inflation Rate		4.14180	0.0003
7 lags order selected by the HQ criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation Rate does not Granger Cause Unemployment Cycle LT	230	1.74107	0.0665
Unemployment Cycle LT does not Granger Cause Inflation Rate		3.40896	0.0002
11 lags order selected by the LR, FPE and AIC criterions			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

2) Quarterly data from 1959:04 to 2019:04.

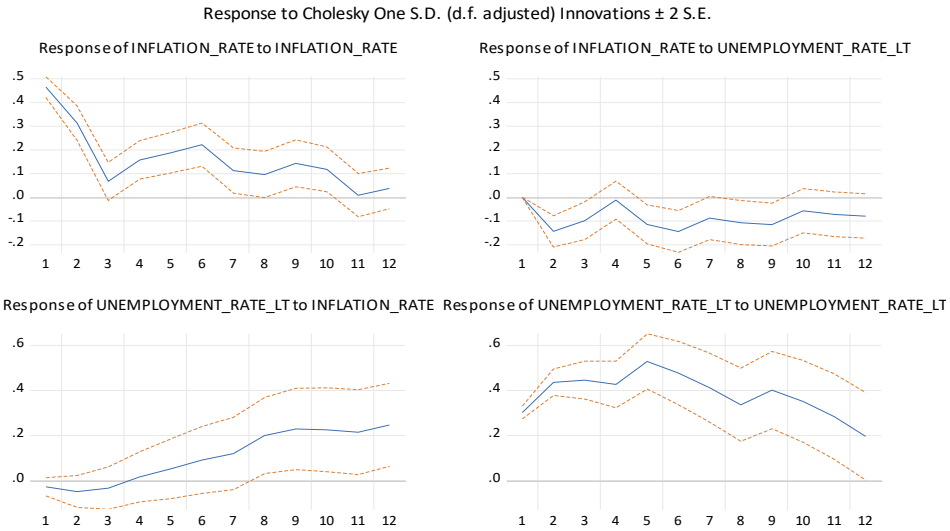

Figure 1B. SVAR analysis: inflation rate and unemployment cycle LT

Table 1C. Granger causality tests (inflation rate &unemployment cycle short term)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation Rate does not Granger Cause Unemployment Cycle ST	235	3.21121	0.0048
Unemployment Cycle ST does not Granger Cause Inflation Rate		3.19020	0.0050
6 lags order selected by the SC criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation Rate does not Granger Cause Unemployment Cycle ST	234	2.84770	0.0073
Unemployment Cycle ST does not Granger Cause Inflation Rate		4.32465	0.0002
7 lags order selected by the HQ criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Inflation Rate does not Granger Cause Unemployment Cycle ST	230	1.75074	0.0646
Unemployment Cycle ST does not Granger Cause Inflation Rate		3.53325	0.0001
11 lags order selected by the LR, FPE and AIC criterions			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

2) Quarterly data from 1959:04 to 2019:04.

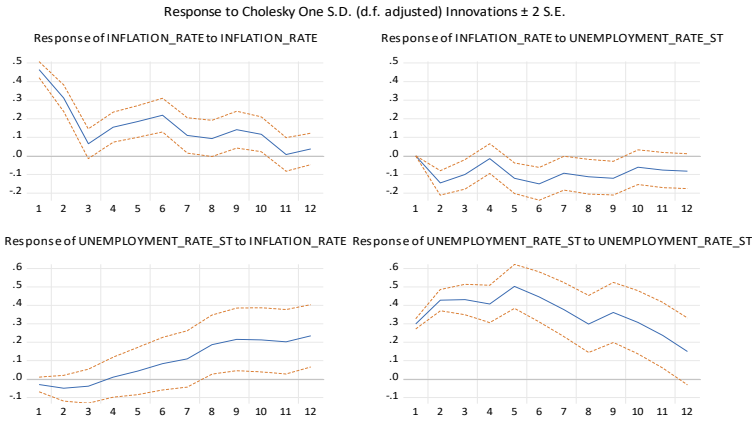

Figure 1C. SVAR analysis: inflation rate and unemployment cycle ST

These empirical results of two-way causality motivated a new investigation on the causality relation between both variables. In this context, one opts for the relation between the unemployment rate and a dispersion measure for the inflation rate in order to get a causality relation in just one direction. In this sense, based on Tables 2A, 2B, and 2C, the Granger causality tests do not accept the null hypothesis as follows:

i) Variance of the inflation rate does not Granger cause unemployment rate; ii) variance of the inflation rate does not Granger cause unemployment rate in the long term and iii) variance of the inflation rate does not Granger cause unemployment rate in the short term. Therefore, the variance of inflation rate shows a one-way causality from variance of inflation rate to three dependent variables: unemployment rate, unemployment cycle in the long term, and unemployment cycle in the short term. Figures 2A, 2B and 2C also display impulse response functions with 6 lags.

Table 2A. Granger causality tests (variance of inflation rate & unemployment rate)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment rate	235	9.10246	7.E-09
Unemployment rate does not Granger Cause Variance of inflation rate		1.14042	0.3398
6 lags order selected by the SC and HQ criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment rate	231	7.48673	4.E-10
Unemployment rate does not Granger Cause Variance of inflation rate		0.79794	0.6308
10 lags order selected by the FPE and AIC criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment rate	228	5.90604	3.E-09
Unemployment rate does not Granger Cause Variance of inflation rate		0.74540	0.7166
13 lags order selected by the LR criterion			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion. 2) Quarterly data from 1959:04 to 2019:04.

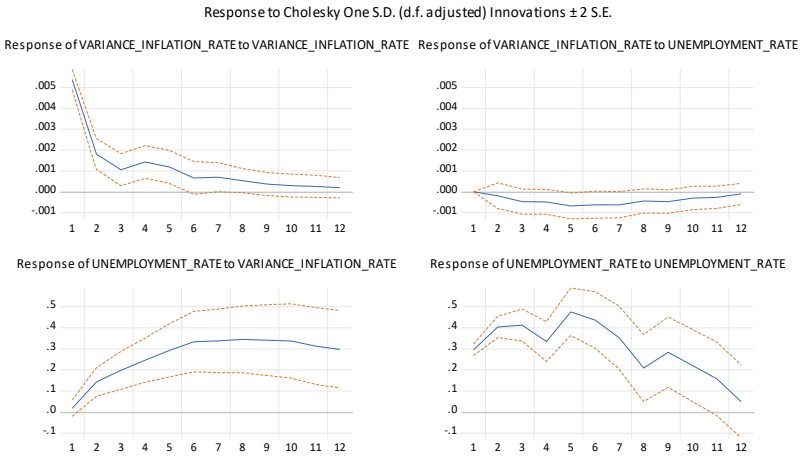

Figure 2A. SVAR analysis: Variance of inflation rate and unemployment rate

Table 2B. Granger causality tests (variance of inflation rate & unemployment cycle LT)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment cycle LT	235	8.70968	2.E-08
Unemployment cycle LT does not Granger Cause Variance of inflation rate		1.30349	0.2566
6 lags order selected by the SC and HQ criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment cycle LT	231	6.96740	2.E-09
Unemployment cycle LT does not Granger Cause Variance of inflation rate		0.89269	0.5409
10 lags order selected by the FPE and AIC criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment cycle LT	228	5.49339	2.E-08
Unemployment cycle LT does not Granger Cause Variance of inflation rate		0.81803	0.6407
13 lags order selected by the LR criterion			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.
2) Quarterly data from 1959:04 to 2019:04.

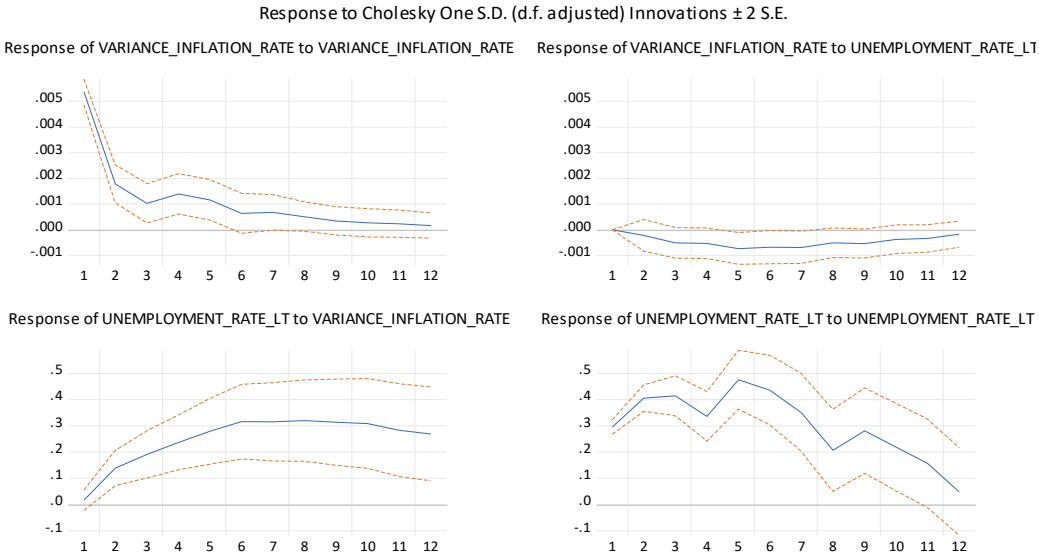

Figure 2B. SVAR analysis: variance of inflation rate and unemployment cycle LT

Table 2C. Granger Causality Tests (Variance of inflation rate & Unemployment cycle ST)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment cycle ST	235	8.75446	1.E-08
Unemployment cycle ST does not Granger Cause Variance of inflation rate		1.29588	0.2601
6 lags order selected by the SC and HQ criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment cycle ST	231	6.96093	2.E-09
Unemployment cycle ST does not Granger Cause Variance of inflation rate		0.88647	0.5467
10 lags order selected by the FPE and AIC criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Variance of inflation rate does not Granger Cause Unemployment cycle ST	228	5.46497	2.E-08
Unemployment cycle ST does not Granger Cause Variance of inflation rate		0.82392	0.6344
13 lags order selected by the LR criterion			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.
2) Quarterly data from 1959:04 to 2019:04.

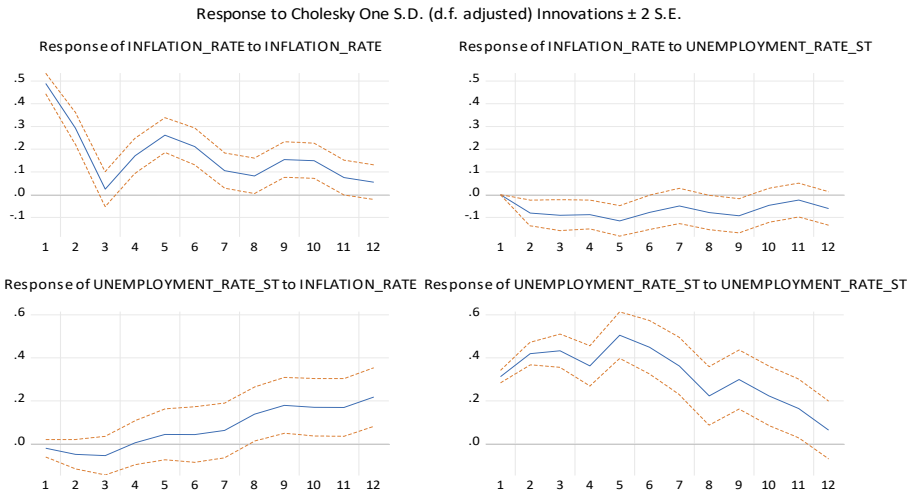

Figure 2C. SVAR analysis: variance of inflation rate and Unemployment cycle ST

Finally, Tables 3A, 3B, and 3C exhibit the Granger causality tests between the business cycle and the three dependent variables. The empirical results reveal a one-way causality from business cycle to all the dependent variables. Figures 3A, 3B and 3C also reveal impulse response functions with 13 lags.

Table 3A. Granger causality tests (business cycle & unemployment rate)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment rate	235	6.98628	8.E-07
Unemployment rate does not Granger Cause Business cycle		1.14042	0.3398
6 lags order selected by the SC criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment rate	232	7.85300	5.E-10
Unemployment rate does not Granger Cause Business cycle		1.54203	0.1348
09 lags order selected by the HQ criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment rate	228	6.17024	1.E-09
Unemployment rate does not Granger Cause Business cycle		1.00158	0.4511
13 lags order selected by the LR, FPE, AIC criterions			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

2) Quarterly data from 1959:04 to 2019:04.

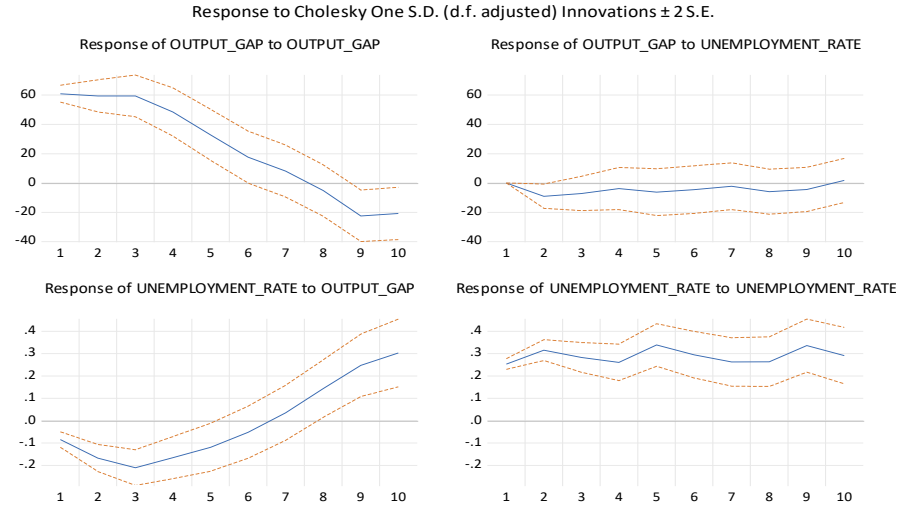

Figure 3A. SVAR analysis: Business cycle and Unemployment rate

Table 3B. Granger causality tests (business cycle unemployment cycle LT)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment cycle LT	235	7.02598	7.E-07
Unemployment cycle LT does not Granger Cause Business cycle		1.17675	0.3197
6 lags order selected by the SC criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment cycle LT	232	7.85264	5.E-10
Unemployment cycle LT does not Granger Cause Business cycle		1.61233	0.1132
09 lags order selected by the HQ criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment cycle LT	228	5.49339	2.E-08
Unemployment cycle LT does not Granger Cause Business cycle		0.81803	0.6407
13 lags order selected by the LR, FPE, AIC criterions			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

2) Quarterly data from 1959:04 to 2019:04.

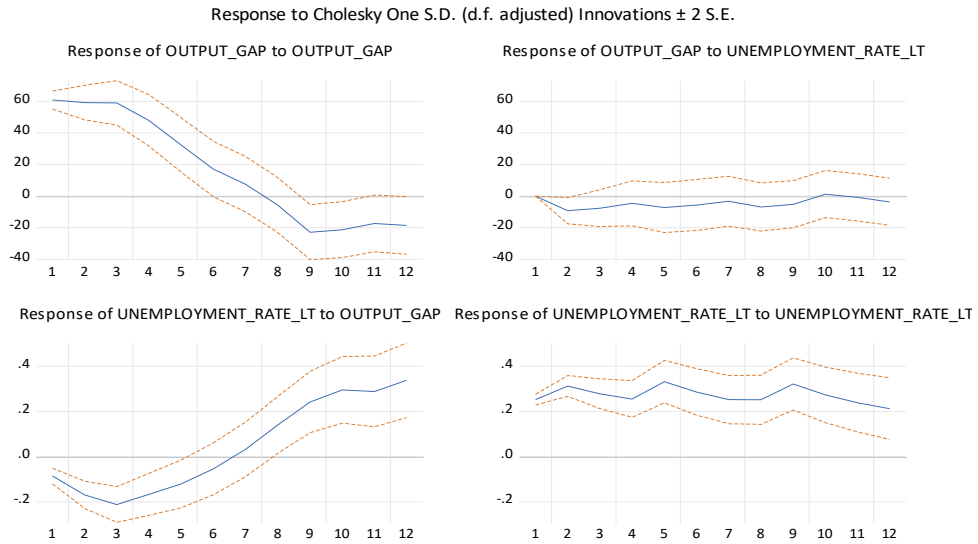

Figure 3B. SVAR analysis: business cycle and unemployment cycle LT

Table 3C. Granger causality tests (business cycle & unemployment cycle ST)

Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment cycle ST	235	7.15638	5.E-07
Unemployment cycle ST does not Granger Cause Business cycle		1.14693	0.3361
6 lags order selected by the SC criterions			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment cycle ST	232	7.76185	7.E-10
Unemployment cycle ST does not Granger Cause Business cycle		1.62203	0.1104
09 lags order selected by the HQ criterion			
Null Hypothesis:	Obs.	F-Statistic	Prob.
Business cycle does not Granger Cause Unemployment cycle ST	228	5.92524	3.E-09
Unemployment cycle ST does not Granger Cause Business cycle		1.06291	0.3935
13 lags order selected by the LR, FPE, AIC criterions			

Note. 1) Criterions - LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

2) Quarterly data from 1959:04 to 2019:04.

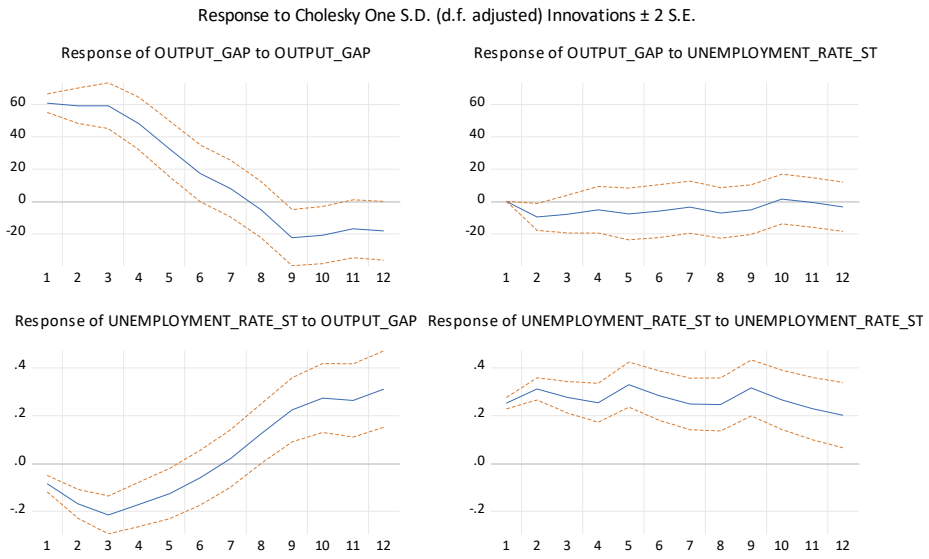

Figure 3C. SVAR analysis: business cycle and unemployment cycle ST

Hence, in next section, one can test equation (2) that shows an econometric specification different from the Phillips curve, so that the variables of unemployment are explained by the variance of inflation rate and by the control variable business cycle. In other words, it is not the unemployment rate that explains the inflation rate according to the Philipps Curve, but here it is the variance of the inflation rate that explains the unemployment rate, taking into account the Granger causality tests.

3.2 Ordinary Last Squares Models

Based on OLS models, Table 5 displays the empirical results of the three models where the second, third and fourth columns show the dependent variables: unemployment rate, unemployment cycles in the long run and short run respectively. There are six lags from each one of the dependent variables in which the estimated coefficients are statistically significant at 1% level. The estimated coefficients in the seventh lag are not statistically significant for the three estimated models.

The explanatory variable business cycle and the main variable of interest, variance of inflation rate, are also statistically significant at 1% level. While the estimated coefficient regarding business cycle is negative, showing that an excess of demand reduces the unemployment rate, as well as unemployment cycles in the long run and short run; the variance of inflation rate has a direct and positive effect on the three dependent variables, i.e., the variance of inflation rate increases the unemployment rate and the unemployment cycle variables.

Table **5.** Method: ordinary least squares (quarterly data from 1959:04 to 2019:04)

Dependent variable	Unemployment rate	Unemployment cycle_LT	Unemployment cycle_ST
	Coefficient	Coefficient	Coefficient
	(Std.Error)	(Std.Error)	(Std.Error)
Constant	0.315647***	-0.013711	-0.013063
	(0.090460)	(0.023036)	(0.022806)
Unemployment rate (-1)	1.306414***	1.303640***	1.289447***
	(0.056840)	(0.056868)	(0.057079)
Unemployment rate (-2)	-0.440991***	-0.444773***	-0.442155***
	(0.064418)	(0.064217)	(0.064015)
Unemployment rate (-3)	-0.132837***	-0.132263***	-0.132575***
	(0.044278)	(0.044182)	(0.043941)
Unemployment rate (-4)	0.875768***	0.874263***	0.870785***
	(0.044577)	(0.044510)	(0.044288)
Unemployment rate (-5)	-1.156331***	-1.155024***	-1.143819***
	(0.065437)	(0.065328)	(0.065205)

Unemployment rate (-6)	0.486954***	0.490998***	0.489203***
	(0.051731)	(0.051561)	(0.051610)
Business cycle	-0.000829***	-0.000841***	-0.000865***
	(0.000204)	(0.000204)	(0.000203)
Variance of inflation rate	1.424647***	1.329957***	1.277388***
	(0.3313021)	(0.3293649)	(0.3270818)
		Statistics	
Adjusted R-squared	0.965464	0.963155	0.959058
Durbin-Watson stat	1.999780	1.989436	1.997370
F-statistic	818.6868	765.6200	686.1724
Prob(F-statistic)	< 0.00001	< 0.00001	< 0.00001
Heteroscedasticity Test	0.6384	0.7658	0.7037
LM test at up to 2 lags	0.9991	0.9715	0.9902

Note. *** = p-value < 0.01; ** = 0.01 < p-value < 0.05; * = 0.05 < p-value < 0.10.

3.3 Robustness Tests

Tables 5A, 5B and 5C present the same empirical models from Table 5 based on robust least squares methods. The empirical results show similarity with the results exhibited in Table 5. However, in order to avoid possible problems of endogeneity it is still necessary to test the empirical models via GMM with IV.

Table 5A. Dependent variable – unemployment rate (1959:04 – 2019:04)

Variables	MODEL 1 - OLS: HAC standard errors & covariance Coefficient (Std.Error)	MODEL 2- Robust Least Squares: (M-estimation) Coefficient (Std.Error)	MODEL 3 – Robust Least Squares: (S-estimation) Coefficient (Std.Error)	MODEL 4 - Robust Least Squares: (MM-estimation) Coefficient (Std.Error)
Constant	0.315647***	0.230931***	0.223643*	0.227907***
	(0.088492)	(0.077260)	(0.126558)	(0.077315)
Unemployment rate (-1)	1.306414***	1.256992***	1.204606***	1.256187***
	(0.063242)	(0.048546)	(0.079522)	(0.048580)
Unemployment rate (-2)	-0.440991***	-0.381083***	-0.408441***	-0.380313***
	(0.067001)	(0.055018)	(0.090125)	(0.055058)
Unemployment rate (-3)	-0.132837***	-0.122603***	-0.093375	-0.121656***
	(0.040734)	(0.037817)	(0.061947)	(0.037844)
Unemployment rate (-4)	0.875768***	0.871230***	0.921902***	0.872629***
	(0.047476)	(0.038072)	(0.062366)	(0.038100)
Unemployment rate (-5)	-1.156331***	-1.102619***	-1.054447***	-1.102796***
	(0.083430)	(0.055888)	(0.091550)	(0.055928)
Unemployment rate (-6)	0.486954***	0.427926***	0.375938***	0.426291***
	(0.049373)	(0.044182)	(0.072375)	(0.044214)
Business cycle	-0.000829***	-0.000462***	-0.000282	-0.000454***
	(0.000299)	(0.000174)	(0.000285)	(0.000174)
Variance of inflation rate	1.424647***	1.249204***	1.211000***	1.242542***
	(0.3267655)	(0.2829581)	(0.4635107)	(0.2831600)
		Statistics		
Adjusted R-squared	0.965464	0.807563	0.837720	0.801874
Durbin-Watson stat	1.999780			
F-statistic	818.6868			
Prob(F-statistic)	< 0.000001			

Note. 1) *** = p-value < 0,01; ** = 0.01 < p-value < 0.05; * = 0.05 < p-value < 0.10.

2) Correlation = Correlation between predicted values and observed values.

Table 5B. Dependent variable: unemployment cycle long term (1959:04 – 2019:04)

Variables	MODEL 1 - OLS: HAC standard errors & covariance Coefficient (Std.Error)	MODEL 2- Robust Least Squares: (M-estimation) Coefficient (Std.Error)	MODEL 3 – Robust Least Squares: (S-estimation) Coefficient (Std.Error)	MODEL 4 - Robust Least Squares: (MM-estimation) Coefficient (Std.Error)
Constant	-0.013711	-0.038087*	-0.054849*	-0.037853*
	(0.025793)	(0.019708)	(0.031411)	(0.019687)
Unemployment cycle LT(-1)	1.303640***	1.253237***	1.178221***	1.254370***
	(0.065797)	(0.048652)	(0.077543)	(0.048601)
Unemployment cycle LT (-2)	-0.444773***	-0.383177***	-0.399490***	-0.384223***
	(0.064917)	(0.054939)	(0.087564)	(0.054882)
Unemployment cycle LT (-3)	-0.132263***	-0.119743***	-0.091847	-0.120880***
	(0.040457)	(0.037799)	(0.060245)	(0.037759)
Unemployment cycle LT (-4)	0.874263***	0.876580***	0.922262***	0.874905***
	(0.047568)	(0.038079)	(0.060692)	(0.038040)
Unemployment cycle LT (-5)	-1.155024***	-1.104515***	-1.051586***	-1.104345***
	(0.081822)	(0.055889)	(0.089078)	(0.055831)
Unemployment cycle LT (-6)	0.490998***	0.427519***	0.375204***	0.429570***
	(0.490998)	(0.044111)	(0.070306)	(0.044065)
Business cycle	-0.000841**	-0.000469***	-0.000442	-0.000477***
	(0.000331)	(0.000175)	(0.000279)	(0.000175)
Variance of inflation rate	1.329957***	1.178406***	1.211130***	1.183865***
	(0.2901932)	(0.2817797)	(0.4491083)	(0.2814848)
		Statistics		
Adjusted R-squared	0.963155	0.785162	0.811803	0.791655
Durbin-Watson stat	1.989436			
F-statistic	765.6200			
Prob(F-statistic)	< 0.00001			

Note. 1) *** = p-value < 0,01; ** = 0.01 < p-value < 0.05; * = 0.05 < p-value < 0.10.

2) Correlation = Correlation between predicted values and observed values.

Table 5C. Dependent variable: unemployment cycle short term (1959:04 - 2019:04)

Variables	MODEL 1 - OLS: HAC standard errors & covariance Coefficient (Std.Error)	MODEL 2- Robust Least Squares: (M-estimation) Coefficient (Std.Error)	MODEL 3 – Robust Least Squares: (S-estimation) Coefficient (Std.Error)	MODEL 4 - Robust Least Squares: (MM-estimation) Coefficient (Std.Error)
Constant	-0.013063	-0.037967*	-0.053709*	-0.037714*
	(0.026473)	(0.019619)	(0.032042)	(0.019601)
Unemployment Cycle ST (-1)	1.289447***	1.244662***	1.181190***	1.245569***
	(0.064854)	(0.049104)	(0.080196)	(0.049059)
Unemployment Cycle ST (-2)	-0.442155***	-0.385314***	-0.396266***	-0.386188***
	(0.064040)	(0.055071)	(0.089941)	(0.055021)
Unemployment Cycle ST (-3)	-0.132575***	-0.121618***	-0.097468	-0.122525***
	(0.039965)	(0.037801)	(0.061737)	(0.037767)
Unemployment Cycle ST (-4)	0.870785***	0.870860***	0.911667***	0.869417***
	(0.047370)	(0.038100)	(0.062224)	(0.038065)
Unemployment Cycle ST (-5)	-1.143819***	-1.094355***	-1.043925***	-1.094295***
	(0.080919)	(0.056094)	(0.091613)	(0.056043)
Unemployment Cycle ST (-6)	0.489203***	0.431457***	0.381035***	0.433184***
	(0.045926)	(0.044399)	(0.072511)	(0.044358)
Business cycle	-0.000865***	-0.000494***	-0.000419	-0.000501***
	(0.000330)	(0.000175)	(0.000285)	(0.000175)
Variance of inflation rate	1.277388***	1.110680***	1.075570**	1.116583***
	(0.3189134)	(0.2813808)	(0.4595490)	(0.2811252)
		Statistics		
Adjusted R-squared	0.959058	0.787597	0.810544	0.793332
Durbin-Watson stat	1.997370			
F-statistic	686.1724			
Prob(F-statistic)	< 0.000001			

Note. 1) *** = p-value < 0,01; ** = 0.01 < p-value < 0.05; * = 0.05 < p-value < 0.10.

2) Correlation = Correlation between predicted values and observed values.

Tables 6 and 7, based on a GMM system of two equations (equations 1 and 2), show three systems:

i) the first one shows the system of two equations so that Model 1A (Table 6) is connected with Model 1B (Table 7); ii) the second one shows the connection between Model 2A (Table 6) and Model 2B (Table 7) and iii) the last one shows the interaction between Model 3A (Table 6) and Model 3B (Table 7).

Table 6 shows that all the estimated coefficients are statistically significant at 1% level, except for the constant terms, which are not statically significant. One stands out that, the variance of real interest rate contributes to reducing the business cycle as expected. In other words, the greater the volatility of the real interest rate is, generating uncertainty and economic instability, the lower incentive for economic agents to make productive investments will be, as well as the lower incentive to obtain credit for consumption or production. Besides, the monetary policy indirectly affects the unemployment rate via business cycle.

In addition, the statistic J does not reject the hypothesis that the instruments are good and, in turn, the Stock-Yogo test, based on the Cragg-Donald F statistic, does not accept the null hypothesis that the instruments are weak. Hence, the instruments are good and valid.

Table 6. Estimation method: GMM (quarterly data from 1959:04 - 2019:04)

	Dependent variables		
	Model 1A	Model 2A	Model 3A
	Business cycle	Business cycle	Business cycle
Constant	5.394881	4.855479	4.806069
	(3.425289)	(3.463795)	(3.466833)
Business cycle (-1)	0.962542***	0.964478***	0.964974***
	(0.021513)	(0.021296)	(0.021257)
Variance of real interest rate	-0.629696***	-0.610645***	-0.611200***
	(0.234411)	(0.229044)	(0.231530)
		Statistics	
Adjusted R-squared	0.736450	0.736324	0.736251
J – Statistics (p-value)	0.131734	0.128546	0.126351
Stock-Yogo test (critical value at 5%)	20.48	20.48	20.48
Cragg-Donald F-stat:	104.2293	104.2293	104.2293

Note. 1) *** = p-value < 0,01; ** = 0.01 < p-value < 0.05; * = 0.05 < p-value < 0.10.

2) Instrument specification: Variance of inflation rate (-1to-6), unemployment_rate*Variance of inflation rate, unemployment_rate*business cycle, Variance of real interest rate(-1to-4), real_gdp*real_interest_rate_cycle, @trend, real_gdp, variance_funds_rate, nrou_long_term*real_interest_rate, nrou_long_term*real_interest_rate.

3) 235 observations.

The empirical results from Table 7 confirm the empirical results already presented regarding the variables business cycle and variance of inflation rate. In this sense, once more, there are empirical evidence regarding the robustness of the empirical results.

Table 7. Estimation method: GMM (Quarterly data from 1959:04 - 2019:04)

	Dependent variables		
	Model 1B	Model 2B	Model 3B
	Unemployment rate	Unemployment rate long term	Unemployment rate Short term
Constant	0.093058	-0.035313***	-0.036172***
	(0.069707)	(0.013953)	(0.014203)
Unemployment rate (-1)	1.563492***	1.561099***	1.555071***
	(0.059068)	(0.060563)	(0.062984)
Unemployment rate (-2)	-0.494603***	-0.499102***	-0.485522***
	(0.087298)	(0.086639)	(0.090541)
Unemployment rate (-3)	-0.475331***	-0.466641***	-0.476219***
	(0.087966)	(0.086167)	(0.087973)
Unemployment rate (-4)	0.932557***	0.928576***	0.899678***
	(0.080381)	(0.080806)	(0.081696)

Unemployment rate (-5)	-1.116475***	-1.126919***	-1.088635***
	(0.110342)	(0.110836)	(0.108495)
Unemployment rate (-6)	0.566225***	0.577238***	0.572164***
	(0.057164)	(0.055137)	(0.055661)
Business cycle	-0.000565***	-0.000573***	-0.000566***
	(0.000181)	(0.000189)	(0.000193)
Variance of inflation rate	1.230249***	1.208248***	1.157638***
	(0.1739121)	(0.1740355)	(0.1738289)
		STATISTICS	
Adjusted R-squared	0.951254	0.948527	0.940709

Note. 1) *** = p-value < 0.01; ** = 0.01 < p-value < 0.05; * = 0.05 < p-value < 0.10.

2) Instrument specification: Variance of inflation rate (-1to-6), unemployment_rate*Variance of inflation rate, unemployment_rate*business cycle, Variance of real interest rate(-1to-4), real_gdp*real_interest_rate_cycle, @trend, real_gdp, variance_funds_rate, nrou_long_term*real_interest_rate, nrou_long_term*real_interest_rate.

3) 235 observations.

The first system is shown by Model 1A in Table 6 and by model 1B in Table 7. Model 1B shows the direct effect of the business cycle on unemployment, with the estimated coefficient value of -0.000565. Nevertheless, based on Model 1A, the indirect effect displays that variance of real interest rate affects the business cycle with the estimated coefficient of -0.629696, and in turn affects the unemployment rate (Model 1B). In this case, the final indirect effect is calculated as (-0.000565)*(-0.629696), which results in a value of 0.000356, according to Moreira *et al* (2016). The indirect effect from the variance of real interest rate on the unemployment rate, via business cycle, is positive as expected. The higher the variance of real interest rate is, the higher the unemployment rate will be. The indirect effect for Models 2A and 2B, as well as 3A and 3B are similar.

4. Discussion

Since correlation does not mean causality, this article asks, firstly, whether there is a one-way causality, so that unemployment rate causes inflation rate, as the original Phillips curve implicitly assumes. The empirical results, based on Granger causality tests, display that there is a two-way causality between them, based on the American economy from 1959:04 to 2019:04. The same result is confirmed when short and long-term unemployment cycles are related to the inflation rate. But, so what? What can public policy make out of these conclusions reached? At the very least, the fundamentals of the original Phillips curve must be questioned.

Considering the mutual causal relationship between inflation and unemployment, new possibilities of investigation are opened between these two variables. Firstly, this article shows that the variance of inflation rate causes the unemployment variables, but the opposite does not occur. Besides, the empirical results show that the variance of inflation rate has a direct and positive effect on the three dependent variables. In other words, the variance of inflation rate increases the unemployment rate and the unemployment cycle variables. This means that there is no trade-off between variance of inflation rate and the three variables associated to unemployment.

Secondly, there is a one-way causality from business cycle to unemployment rate, as well as unemployment cycles of long and short term. In this context, the estimated coefficient regarding business cycle is negative, showing that an excess of demand reduces unemployment rate variables. This is one more interesting result, because generally these variables are considering proxies between them. This empirical result suggests that the business cycle precedes the unemployment and that, therefore, the variables of unemployment react later to the business cycle effect. Hence, the unemployment variables adjust more slowly, possibly due to greater rigidity in the labor market.

At last, the variance of real interest rate contributes to reducing the business cycle as expected. Hence, the monetary policy indirectly affects the unemployment rate via business cycle. The indirect effect from the variance of real interest rate on the unemployment rate via business cycle is positive as expected. The higher the variance of real interest rate is, the higher the unemployment rate will be. The results are similar considering the unemployment cycle variables.

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