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Real wages, real interest rates, and the Phillips curve

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This article argues that any analysis of a Phillips curve should include the real interest rate in addition to inflation and real wages as any changes in the interest rate changes the labour–capital input mix in the production process leading to a change in the level of employment in the economy. To justify this argument a Phillips curve model is developed, which includes the real interest rate in addition to inflation and real wages. After the diagnosis of the time series properties of the data, an error correction model is developed and estimated using a set of US annual data from 1948 to 1996. The estimated parameters of the model do suggest that one should really take into consideration of the real interest rate while analysing the Phillips curve. A non-nested test (F-test) also suggests that the Phillips curve model with real interest rate as an additional variable performs better than the conventional method that does not include the real interest rate.

I. Introduction

This article argues that while analysing the Phillips curve, economists need to take the effect of a change in the real interest rates into consideration along with other factors such as any changes in the real wages. Section II of this paper presents the basic background of the study, which primarily includes a review of literature on both the theoretical and empirical aspects of the Phillips curve. Section III of the paper presents the methodology and the description of the data used in the study. The empirical findings are reported in Section IV. A summary and conclusion are provided in Section V.

II. Background to the Study

The prospect of temporary trade-offs between inflation and unemployment has served as a major point of contention between the different schools of economic thought (Barro, 1984; Wulwick, 1987; McCallum *et al.*, 1988). For instance the Monetarists argue that an expansionary monetary policy can produce only a temporary decrease in unemployment rate due to the misperception on the part of producers. However, once prices rise there will be a temporary misperception on the part of labour concerning its real wage rate. Central to the existence of the short-run Phillips curve (SRPC) is the fact that the labour agents do not immediately realize a decrease in their real wage in comparison to government benefits for the unemployed (Friedman, 1968, 1970, 1976, 1977). Furthermore, as wage earners incorporate inflationary expectations into their behaviour the increasing levels of inflation would create sufficient money illusion, which brings the real wages down leading the economy to temporarily operate on the SRPC (Laidler, 1981; Perry, 1986).

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Although Tobin (1981) emphasizes the similarities between the Monetarist and Rational Expectationist Theories, the Rational Expectationist theory is less akin to accepting the Monetarist framework of the short- and long-run time periods (Hoover, 1984). A Phillips curve based on complete rational expectations would be vertical even in the short run because only ‘surprise’ or unexpected inflation can have an impact on the economy. Otherwise there is money neutrality (Lucas, 1972; Barro, 1976, 1984; Sargent, 1979; Lucas and Sargent, 1981). Rational Expectationists argue that the short-run trade-off between inflation and unemployment (SRPC) is due to short-term imperfect information, which is not possible in the long run.

Neo-Keynesians believe that unanticipated monetary and fiscal policies have the greatest impact on the economy; however Neo-Keynesians differ sharply with the Rational Expectationists in that Neo-Keynesians believe that even anticipated policies may still have an impact on the economy (Mishkin, 2002). Neo-Keynesians, also point out that wages and prices can adjust slowly, which in turn can result in macroeconomic fluctuations (Mankiw, 1989, 1993, 1997; Berndt, 1991; Fair, 1999). Some empirical studies in this regard certainly indicate the evidence of the existence of a Phillips curve with temporary trade-offs between inflation and unemployment, due to the rigidities in wages and prices (Humphrey, 1978; Taylor, 1980; Blinder, 1987; Koustas, 1988; Fortin, 1991; Prachowny, 1991; Gali, 1992; Fuhrer, 1995; Dutkowsky, 1996). Romer (1993), a self-described neo-Keynesian economist, argues ‘monetary and other aggregate demand shocks are a necessary part of any complete model of macroeconomic fluctuations’. Likewise Gordon (1990) believes that increased attention to industrial organization will help economists to better understand the reality that markets do not always quickly clear, both in the product market and the input market. The economy shifting from operating on the short-run Phillips curve (SRPC) to the long-run Phillips curve (LRPC) comes partly from the fact that real input costs are not ascertained in the short run, although they are in the long run.

Mankiw (1997) describes the Phillips curve as the short-run aggregate supply curve (SRAC), which essentially describes the supply side of the economy. The SRAC can provide a valid description of the supply side of the economy, until the prices of all inputs increase proportionately to the same level as the output prices. For this reason in the model used in this study we include both the cost of labour (real wages) and capital (real interest). Landskroner and Ruthenberg (1989) have documented that the great majority of commercial loans now are of a variable interest rate nature. Therefore, the real interest rate that entrepreneurs pay over the life of a loan may vary just as the real wage that workers receive may vary.

Graphical description

The Phillips curves in Fig. 1 presents both the LRPC as well as the SRPC. Assume initially the economy is operating at point A on $SRPC_0$. An unanticipated inflation, the difference between π_2 and π_1, creates a money illusion leading the economy to move from point A to point B. Once the economic agents realize that they had not anticipated the true inflation rate, the economy shifts to point C. Both temporary misconceptions regarding the real wage and the real net present value (NPVr) allow the economy to operate on a SRPC. Eventually the labour agents realize the increase in the cost of living leading to a decline in real wage and the entrepreneurs realize the increase in the cost of capital leading to a decrease in the NPVr for capital/labour complementary projects, and at the same time an increase in the demand for the products of entrepreneurs has not been sustained. Then the ability of policy makers to use money illusion to operate on the SRPC is lost. At that point, the economy comes back to natural unemployment rate on the LRPC, due to some workers opting for unemployment and some capital/labour complementary projects being curtailed, with attendant layoff. Obviously, under this circumstance the effect of real interest rate on aggregate demand would also be important to the unemployment rate.

Figure 2 shows the effect of a change in the real interest rate on the capital and labour inputs used by a firm and its output as a result. Assume initially the firm is operating at point A (the tangent point between the isoquant and the isocost curves). Holding the real wage constant (price of labour) if the real interest rate (price of capital) is increased the isocost line will shift inward leading to the firm to operate at point B (lower level of output). As

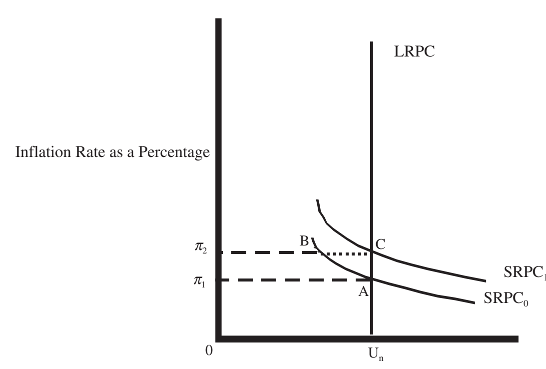

Fig. 1. The Phillips curves

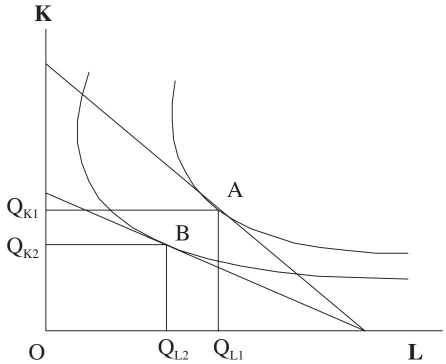

Fig. 2. Effects of real interest rate change on capital (K) and labour (L) use

demonstrated in Fig. 2 the firm now not only reduces the use of capital input (due to higher cost of capital) but also reduces the use of labour input because of a lower level of output. This in turn affects the unemployment rate in the economy.

III. Methodology

Based on the discussions in Section II the following model is developed, which includes the real interest rate as an additional explanatory variable, in addition to the usual explanatory variables such as the real wages and inflation to explain the level of unemployment in the economy.

$$U_d = f(\pi, r, w) \quad (1)$$

where U_d is the deviation of unemployment rate from its natural rate, π is the inflation rate, r is the real interest rate and w is the real wages. The Phillips curve, which is based on the standard Keynesian macroeconomics, suggests that unemployment rate and the inflation are inversely related with each other. Therefore, the existence of Phillips curve would expect π and U_d to be inversely related with each other and as a result π would carry a negative coefficient. According to Gordon (1978) and Shapiro (1987), an increase in real cost of production, such as an increase in real wages (w), will lead to a supply shock in the economy leading to an increase in the level of unemployment. This suggests that w should carry a positive coefficient. As discussed in the previous section, an increase in the real interest rate may also lead to a supply shock in the economy (in addition the demand shock) resulting in an increase in the unemployment rate. Therefore, it is expected that the interest rate variable r would carry a positive coefficient.

US annual time series data from 1948 to 1996 are used. Details of data sources and definitions are reported in the Appendix. The descriptive statistics of the data are presented in Table 1. The descriptive statistics are categorized based on whether the difference between the actual rate of unemployment and the natural rate of unemployment ($U_d = U - U_n$) is negative, zero or positive. Generally speaking if U_d is negative or positive the Phillips curve is operating in the short run, if zero then the Phillips curve is operating in the long run. The descriptive statistics in the table indicates that the average values of explanatory variables are higher when U_d is positive.

Table 1. Unit root test

	ADF		P–P	
Variable	Level	FD	Level	FD
U_d	−2.88	−5.74**	−2.91	−6.23**
Π	−2.99	−7.89**	−3.39*	−8.80**
w	−1.37	−5.84**	−1.33	−4.13*
r	−3.10	−8.18**	−4.64**	−9.65**

ADF = augmented Dickey_Fuller test, P–P = Phillips–Perron test, FD = first difference. ** significant at 1% level, * significant at 5% level.
Critical values are derived from MacKinnon (1990).

IV. Estimation of the Model

Since macroeconomic time series data often shows a unit root process (Nelson and Plosser, 1982) unit root tests were conducted with all the data series. For that initially an augmented Dickey–Fuller test was conducted. This involves estimating the following regression and carrying out unit root tests:

$$\Delta X_t = \alpha_0 + \rho t + \beta X_{t-1} + \sum_{i=1}^{n} \lambda_i \Delta X_{t-i} + \epsilon_t \quad (2)$$

where X is the variable under consideration, Δ is the first difference operator, t is a time trend, and ϵ is a stationary random error term. If the null hypothesis that $\beta = 0$ is not rejected, the variable series contains a unit root and is non-stationary. The optimal lag length in the above equation is identified by ensuring that the error term is a white noise. The test results are reported in Table 1. Second, in addition to the augmented Dickey–Fuller test, a Phillips–Perron test (Phillips, 1987; Phillips and Perron, 1988) is also conducted to check for data series stationarity. The Phillips–Perron test uses a non-parametric correction to deal with any correlation in the error terms. This test is more powerful than the Dickey–Fuller test and it is more appropriate with small samples. Both the Dickey–Fuller and Phillips–Perron tests indicate that all of the data series in the sample are non-stationary in level form. Therefore, the same tests are performed on the first differences. The test results are reported in Table 2. The results suggest that all the series are stationary at first difference level (integrated of order one).

Having established the stationarity of the data, we use the Johansen (1988), and Johansen and Juselius (1990) approaches to explore any long-run equilibrium relationship between the variables. This involves testing the cointegrating vectors. Consider a p dimensional vector autoregression,

$$X_t = \sum_{i=1}^{k} \Pi_i X_{t-i} + c + \varepsilon_t \tag{3}$$

which can be written as

$$\Delta X_t = \sum_{i=1}^{k} \Gamma_i \Delta X_{t-k} - \Pi X_{t-k} + c + \varepsilon_t \tag{4}$$

where

$$\Gamma_i = -I + \Pi_1 + \Pi_2 + \cdots + \Pi_t \tag{5}$$

$$i = 1, 2, \ldots, k-1 \quad \text{and}$$

$$\Pi = I - \Pi_1 - \Pi_2 - \cdots - \Pi_k \tag{6}$$

In Equation 6, p is equal to the number of variables under consideration. The matrix Π captures the long-term relationship between the p variables. The matrix Π can be decomposed into two matrices, Q and R, such that $\Pi = QR'$. Q is interpreted as a vector error-correction parameter and R as cointegrating vectors. This procedure is used to test the existence of a long-run relationship between all the variables in Equation 1 and also between U_d, $INFL$ and W (conventional Phillips curve model). Both results are reported in Tables 2 and 3 respectively. Accordingly Table 4 reports the cointegrated vectors normalized on U_d for both models. As reported in Tables 2 and 3 the null hypothesis of no cointegration could not be rejected.

Since the null hypothesis of no cointegration could not be rejected, as suggested by Engle and Granger (1987) the following error correction model from Equation 3 is developed.

$$\begin{aligned}\Delta U_d = b_0 + b_1\Delta\pi + b_2\Delta\pi_{-1} + b_3\Delta\pi_{-2} + b_4\Delta r \\ + b_5\Delta r_{-1} + b_6\Delta r_{-2} + b_7\Delta w + b_8\Delta w_{-1} \\ + b_9\Delta w_{-2} + b_{10}ERR_{-1} + u_1\end{aligned} \tag{7}$$

Likewise the error correction model for the conventional Phillips curve will be as follows:

$$\begin{aligned}\Delta U_d = b_0 + b_1\Delta\pi + b_2\Delta\pi_{-1} + b_3\Delta\pi_{-2} + b_4\Delta w \\ + b_5\Delta w_{-1} + b_6\Delta w_{-2} + b_7 ERR_{-1} + u_2\end{aligned} \tag{8}$$

EC in Equation 7 is the estimated error term from Equation 1 and in Equation 8 it is derived from estimation of the standard Phillips curve, which does not include the interest rate variable. Assuming that all the macro economic adjustments are completed within two years for each explanatory variables two lags are included. The estimation of Equations 7 and 8 are reported in Table 5.

Consistent with expectations of the Phillips curve, the estimated coefficient of inflation (π) carries a negative and statistically significant coefficient in both estimations. The estimated coefficient of π suggests that a 1% increase in inflation rate lowers the unemployment by approximately 0.5%. The lag effects however are positive (in Equation 7), probably because over time the agents in the economy change their behaviour in accordance with the inflationary condition leading to a higher level of unemployment. The contemporaneous effect of Δw on unemployment is found to be negative. In a growing economy, with increases in productivity the demand for labour may also increase leading to higher wages and lower unemployment in the economy. Indeed, that is precisely what happened during the economic booms of the late 1950s, 1960s and 1990s. The lag effects (in Equation 7), however, are consistent with the theory.

The main purpose of this paper is to argue that any estimation of the Phillips curve should include the interest rate in the model in addition to traditional

Table 2. Johansen's cointegration test (variables U_d, r, w, π)

Ho	Eigenvalue	Likelihood ratio	5% critical value	1% critical value
$r = 0$	0.501	67.80*	62.99	70.05
$r \leq 1$	0.294	35.83	42.44	48.45
$r \leq 2$	0.212	19.81	25.32	30.45
$r \leq 3$	0.175	8.86	12.25	16.26

* Rejection of hypothesis at 5% significance level.

Table 3. Johansen's cointegration test (variables U_d, w, π)

Ho	Eigenvalue	Likelihood ratio	5% critical value	1% critical value
$r = 0$	0.449	43.34**	34.91	41.07
$r \leq 1$	0.180	15.95	19.96	24.60
$r \leq 2$	0.137	6.80	9.24	12.97

** Rejection of hypothesis at 1% significance level.

Table 4. Cointegrated vectors normalized on U_d

	Coefficient	
Variable	Equation 1	Conventional Phillips curve
π	0.24 (0.169)	−0.049 (0.116)
r	0.21 (0.153)	
w	0.48 (0.455)	0.329 (0.309)

Figures in parentheses represent standard error of the corresponding coefficient.

Table 5. Estimation of Equations 7 and 8

	Equation 7		Equation 8	
Variable	coefficient	*t*-value	coefficient	*t*-value
Const.	0.048	0.403	0.201	1.55
$\Delta\pi$	−0.458	5.07***	−0.396	4.44***
$\Delta\pi_{-1}$	0.059	0.536	−0.203	2.19**
$\Delta\Pi_{-2}$	0.185	1.91*	−0.118	1.60
Δw	−5.76	3.90***	−5.59	3.63***
Δw_{-1}	3.071	1.68*	−0.655	0.33
Δw_{-2}	1.061	0.75	1.377	0.087
Δr	−0.212	2.65**		
Δr_{-1}	0.119	1.24		
Δr_{-2}	0.175	2.14**		
ERR_{-1}	−0.268	2.32**	−0.585	4.75***
Adj R^2	0.662	0.529		
F	8.40		8.00	
D. W.	1.73		1.52	
ARCH F	1.106		0.26	
Breusch–Goedfrey LM	0.83		1.82	

*** significant at 1% level, ** significant at 5% level, * significant at 10% level.

variables such as wage and inflation. Therefore, the main focus of this study is the coefficient of the interest rate. The coefficient of Δr is negative, which is consistent with the idea that the immediate effect of an increase in investment in the economy will have a lower level of unemployment as more labours are needed to complement with a higher level of investment. However, over time with the increase in the cost of capital, the use of capital may decrease (because the current investment decisions are made in the past and the future investment decisions are made at current period), which in turn may raise the level of unemployment in the economy. For that reason the coefficient of lags of Δr can carry positive signs.

Equation 8 is estimated to compare the performance of the traditional method of estimating the Phillips curve with the one proposed in Equation 1. Estimation of Equation 8 also exhibits consistency with the expectations of the Phillips curve in terms of the signs of coefficients. While comparing the estimation of Equation 7 and Equation 8, we see that inclusion of the interest rate variable increased the explanatory power of the model by more than 25%. The increased F-value also suggests that the inclusion of the real interest rate decreased in the standard error in estimation. Following Gujarati (1995) to identify whether the three explanatory variables (π, w, r) model performs better than the traditional Phillips curve model (without r), an F-test is conducted. The calculated F-value is 6.55, which is statistically significant at the 1% level, suggests that the unrestricted model (the model that includes interest rate as well as another explanatory variable) performs better. This finding helps to validate the proposition we made in the beginning of the paper that is any estimation of the Phillips curve should also include changes in the real interest rate in addition to any changes in the real wage rate.

The coefficients associated with lag of the error term (*ERR-1*) in the error correction models of Equations 7 and 8 indicate that the traditional Phillips curve model takes about two years to come back to the long-run equilibrium once it strays away from it. The newly formulated model indicated that it takes actually about 4 years for the equilibrium to return. The result of Equation 8 is more consistent with the historical observation on the Phillips curve supporting even more towards the need for incorporating interest rate in describing the Phillips curve phenomena.

V. Summary and Conclusions

This article has argued that any analysis of Phillips curve should include the real interest rate in addition to inflation and real wages as any changes in the interest rate changes the labour input mix in the production process leading to a change in the level of employment in the economy. To justify this issue, a Phillips curve model was developed which included the real interest rate in addition to inflation and real wages as explanatory variables to explain the unemployment rate in the economy. To test the proposition, a set of US annual data series from 1948 to 1996 was used. Before estimating the model time series properties of the data were diagnosed. Since the data series exhibited the integration of order one cointegration tests were conducted. The test revealed that the null hypothesis of no cointegration could not be rejected and as result an error correction model was developed and estimated. The estimated coefficients of real interest rate supported our proposition. In addition, we also conducted a test to identify whether our model performs better in comparison to the traditional Phillips curve model. The test results suggest that the model that included real interest along with the traditional variables performed better.

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Appendix

Data definition and sources

Variable	Definition	Sources
U	Employment rate	Saint Louis Federal Reserve Bank, 1997
K	Prime rate	Saint Louis Federal Reserve Bank, 1997
π	Inflation Rate	Saint Louis Federal Reserve Bank, 1997
W_R	Real wage rate (base 1982)	Bureau of Labour Statistics, 1997
U_n	Natural rate of unemployment	Gordon (1997a, 1997b)
$K_R(K-\pi)$	Real interest rate	

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