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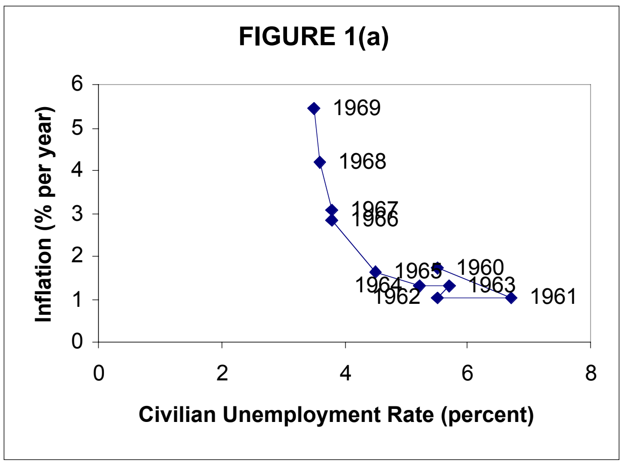
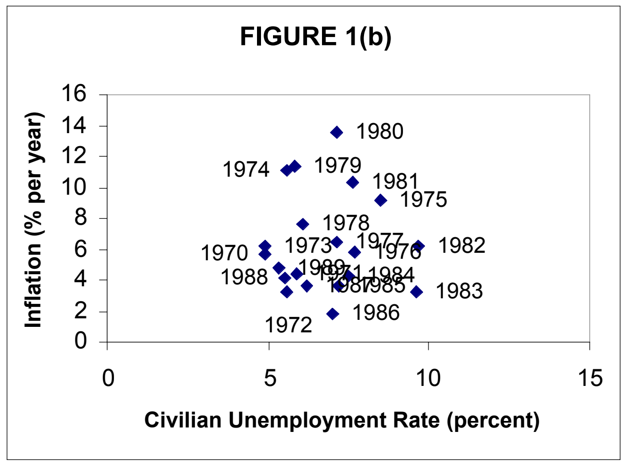
I. INTRODUCTION

In 1958, A. W. Phillips published an article that examined the existence of a negative relationship between nominal wage growth and unemployment from 1861 to 1957 in Britain. Economists soon modified the Phillips curve theory to focus on the growth of prices in relation to unemployment and found an empirical relationship in several countries and time periods throughout the 1950s and 1960s. Figure 1(a) illustrates the stable relationship that exited between 1960 and 1969 in the United States, which was a confirmation for many economists that there was a robust relationship between unemployment and inflation.

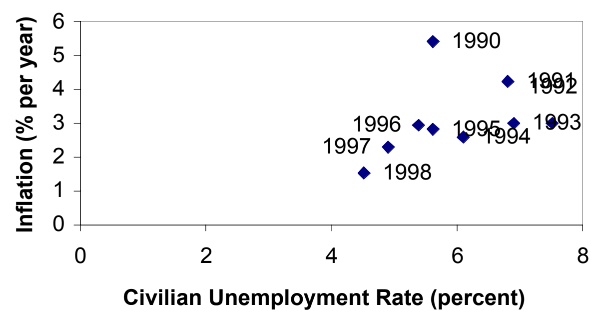




Policy makers saw the Phillips curve as offering a “menu” of choices in which they could choose a level of inflation and unemployment (Able and Bernanke, 1998). By accepting some inflation, policy makers could keep unemployment rates low. However, in the 1970s and 80s, the empirical Phillips curve relationship disappeared, shown by the scatter plot of inflation versus unemployment for 1970 to 1996 in Figure 1(b). As economists tried to explain what was happening to the relationship, they modified the theory behind the Phillips Curve.

Currently, there is debate over the ability of economists to predict the inflation rate. Classical economists argue that because people have rational expectations and markets respond quickly to changes in prices and wages, the Phillips curve relationship does not offer a stable trade-off between inflation and unemployment as the curve shifts rapidly. Keynesian economists, however, argue that the Phillips curve relationship offers policy makers a choice, at least in the short run, to increase inflation and lower unemployment. As shown in Figure 1(c) it is difficult to distinguish one single Phillips curve in the 1990s, instead, the curve seems to be continuously shifting. In an article by David Wessel on 2 April 1999, the *Wall Street Journal* reported that, "Fed officials are increasingly skeptical about the ability of economists to predict inflation based on historic relationships among economic growth, unemployment rates and price increases." Additionally, in 1996, there was debate at a National Bureau of Economic Research conference about whether there would be losses in GDP and rising unemployment associated with policies aimed at reducing inflation below 2-3% (Akerlof, Dickens, and Perry, 1996). As both inflation and unemployment are associated with costs to society, the government needs an accurate prediction of unemployment and inflation in order to pursue policies that minimize their effects.

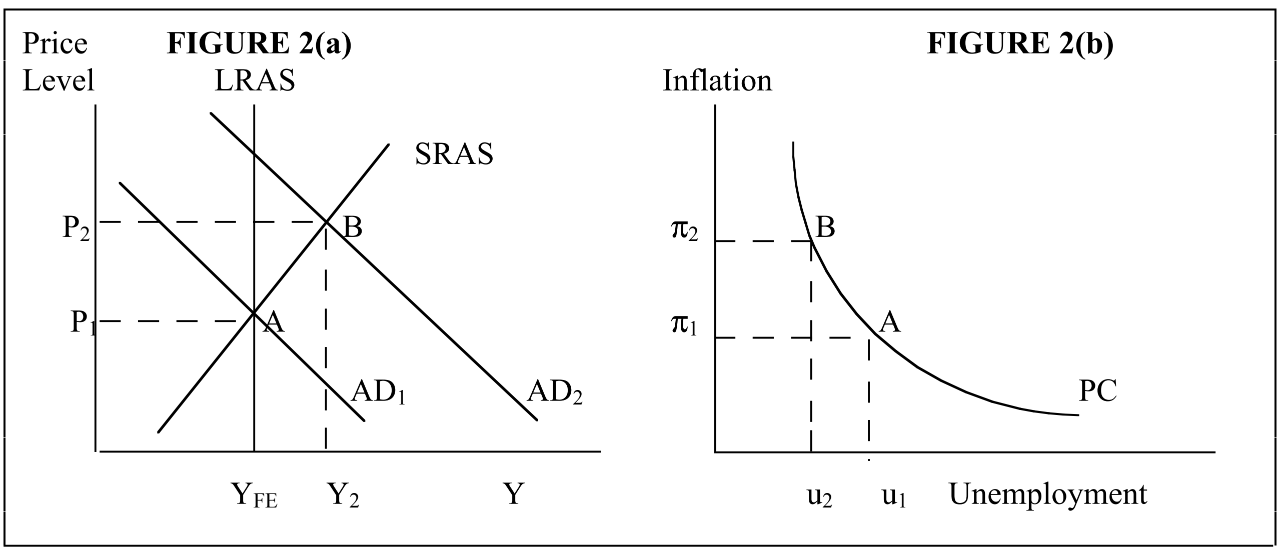
FIGURE 1(c)



This paper will explore whether or not the Phillips curve relationship exists for the 1990s. I will attempt to estimate a Phillips curve for the past decade using data for the United States. In section two, I will explain the theory behind the Phillips curve and how the theory has evolved. In section three, I will present a literature review discussing previous research and results. Section four will present my empirical model and data. In section 5, I will present my results and discuss econometric problems such as serial correlation that may lead to biased estimates. In section six I will briefly conclude the paper.

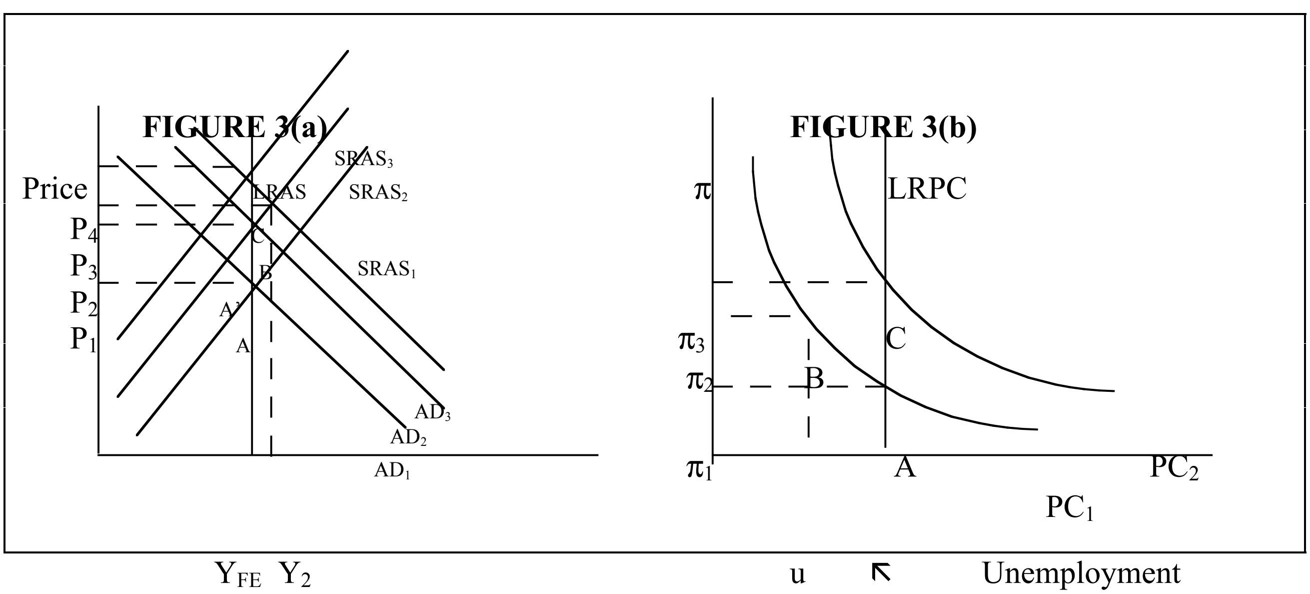
II. THEORY BEHIND THE PHILLIPS CURVE

Initially, Phillips argued that if the demand for labor increased due to an expansionary monetary policy, the unemployment rate would fall causing wages to rise, and creating a trade-off between inflation and unemployment. Economists soon modified Phillips' original theory in order to target prices instead of wages, as an increase in wages would be passed onto the consumers in the form of higher prices. In Figure 2(a), the economy is initially in long-run equilibrium. The output is Y_{FE} and the price level is P_1. If the government were to pursue an expansionary monetary policy, the aggregate demand curve would shift to the right from AD_1 to AD_2. The policy has the effect of increasing the price level from P_1 to P_2 and output in the economy has now increased to Y_2. As prices



have risen, producers increase their output in the short run so that for a period, accepting higher inflation will reduce unemployment. Figure 2(b) is the corresponding Phillips curve. With the shift in aggregate demand, there is a movement along PC from point A to B, and thus the economy has increased inflation from π_1 to π_2 and decreased the unemployment rate from u_1 to u_2. Thus it seems that there is a trade-off; by accepting a little inflation, the government can pursue a policy to decrease unemployment.

In 1968, Friedman and Phelps attacked the Phillips curve on theoretical grounds as they argued that workers and employers are concerned with real wages, not nominal wages, thus deriving the expectations-augmented Phillips curve (*The Economist*, 1994). They argued that there should not be a stable negative relationship between inflation and unemployment, but instead between unanticipated inflation and cyclical unemployment.[1] Based on misperceptions theory, Friedman and Phelps assume that individuals have rational expectations, but they sometimes misjudge economic indicators. Thus, individuals sometimes make mistakes in their predictions of the level of prices in the next period. In Figure 3(a), we see that the economy is initially in long-run equilibrium with price level P_1 and full employment output Y_{FE}. In this first case, we will assume that the money supply increases by 10% every year and has been doing so for many years. The increase in the money supply will cause the aggregate demand to shift outwards from AD_1 to AD_2. Without a change in policy or other observable factors, each worker assumes that prices will rise by 10% and so he or she negotiates wage increases each year of 10%. As employees become relatively more expensive, the nominal costs of production rise, and so the short run aggregate supply curve shifts back to $SRAS_2$ by the same expected 10% increase in costs. As a result, the economy does not experience any change in full-employment output,



although prices rise, and there is no cyclical unemployment as employment has stayed at the natural rate. In Figure 3(b), we see that every year inflation is expected to be 10%, so there is no movement of the Phillips curve. The inflation rate is constant at $\pi_1$and unemployment stays at ↖, the natural rate of unemployment.

In order to produce unexpected inflation, imagine that the money supply is increased by 15% unexpectedly. In this case, as workers have misperceptions about the future price level, they negotiate a 10% increase in the wage level. In Figure 3(a), the aggregate demand has shifted from AD_1 to AD_3, but the short run aggregate supply curve has only shifted back by the expected 10% increase in the price level from $SRAS_1$ to $SRAS_2$. In this case, the economy is producing above full-employment output at Y_2 and the price level is P_3 (at point B). In Figure 3(b), we see that initially there is a movement along the Phillips curve (PC_1) from A to B as people do not realize that prices are rising faster than nominal wages. By increasing inflation from π_1 to π_2 unexpectedly, policy makers are able to achieve lower levels of unemployment, but only for a short period of time. According to rational expectations, as soon as workers realize their mistake, they will renegotiate their wages, $SRAS_2$ will shift back to $SRAS_3$, and the price level will increase further to P_4. In Figure 3(b), the short run Phillips curve then shifts up with the adjustment of aggregate supply, so that the inflation rate increases further to π_3 and unemployment falls back to ↖. The economy will eventually move back to full employment output, but at the cost of much higher inflation in the long-run.

The main conclusion of the expectations-augmented Phillips curve is that there are other factors, besides the current unemployment rate, that affect the Phillips curve and cause it to shift. Therefore, when modeling inflation researchers must include a measure of expected inflation. One obvious candidate for expected inflation is the inflation rate in the previous quarter. As long as there is no change in policy or some exogenous shock to the economy, the inflation rate in the previous quarter(s) should be a good predictor of the current inflation rate.

The Phillips curve relationship will also be altered by supply shocks. If there is an adverse supply shock, for example the price of energy rises dramatically, then the inflation rate will increase as production becomes more expensive. In Figure 4(a), the economy is initially at full employment output, Y_{FE}, and price level P_1. As higher prices for energy would cause production prices to increase, we would expect the short run aggregate supply curve to shift to the left from $SRAS_1$ to $SRAS_2$. The shock will cause the price level to rise from P_1 to P_2 and the economy will produce below full

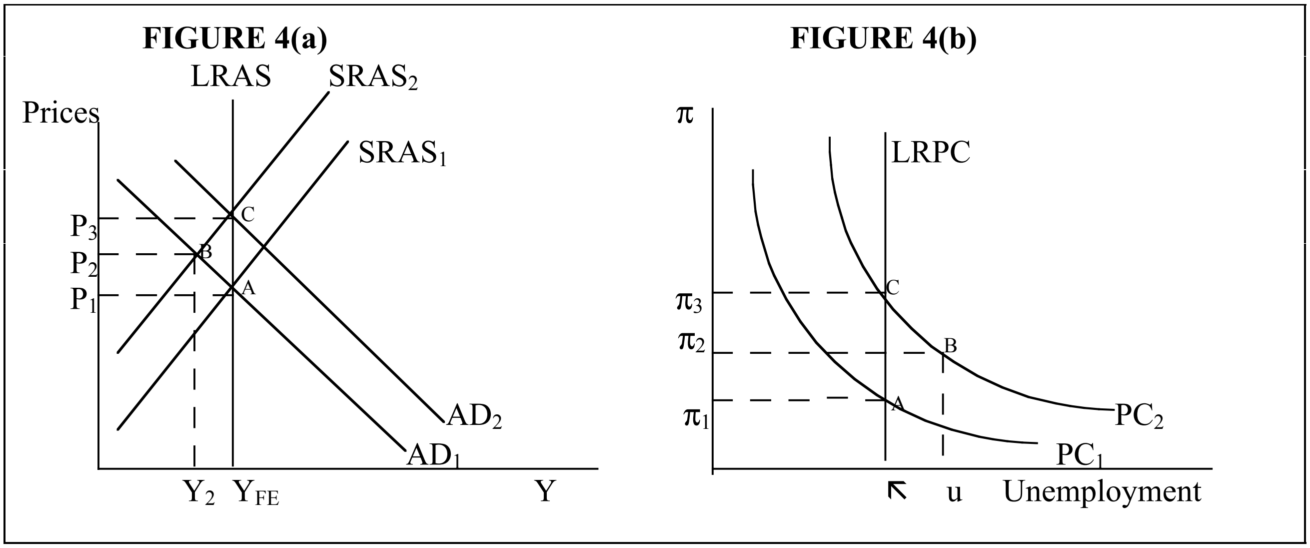
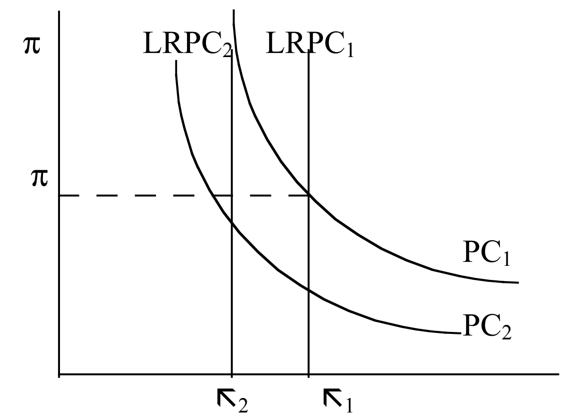


FIGURE 4(a) FIGURE 4(b)

employment output at Y_2. To offset the loss in employment and output, the government might engage in expansionary monetary policies in order to alleviate the rise in the unemployment rate, further increasing inflation by shifting the aggregate demand curve out from AD_1 to AD_2 and bringing the economy back into long run equilibrium at P_3 and Y_{FE} (Abel and Bernanke, 1998). The corresponding Phillips curve is in Figure 4(b). Initially in long run equilibrium, the inflation rate is π_1 and unemployment rate is ↖. With the supply shock, there is a shift up of the Phillips curve from PC_1 to PC_2 as prices rise and unemployment increases from ↖ to u. As the monetary policy is put into effect, there is a movement back along PC_2 from point B to C, increasing inflation further to π_3 while bringing the economy back to the natural rate of unemployment. The movement from A to C will only occur if monetary and fiscal policy are used. If not, unemployment will persist until the relative prices of inputs adjust and the aggregate supply curve shifts back to the right as a result.

FIGURE 5



Other supply shocks, such as a productivity shock, could alter the natural rate of unemployment which would cause a shift in the Phillips curve. Figure 5 illustrates a long run change in the Phillips curve relationship as a result of an increase in the productivity of the economy. If we imagine that the natural rate of unemployment, $\nwarrow$ decreases from $\nwarrow_1$ to $\nwarrow_2$, and the expected inflation rate does not change, then the short run Phillips curve will shift to the left from PC_1 to PC_2 (Abel and Bernanke, 1998). Thus, similar to a change in the expected inflation rate, a change in the natural rate could cause a shift of the short-run Phillips curve.

As illustrated above, in order to estimate the Phillips curve, one would need to measure more than just the inflation rate and the unemployment rate in order to control for people's expectations. One might want to include a measure of the lagged inflation rate in order to measure expectations of the inflation rate. In addition, one would want to include variables that control for supply shocks such as changes in energy prices, relative prices of imports, or changes in the productivity growth of the economy.

Yet, measuring the Phillips curve creates many difficulties. First of all, there are data problems as there is no perfect measure of the inflation rate. Should one use the GDP implicit price deflator, the CPI, core CPI, or some sort of chain-weighted index? Second, there are many other shocks that are difficult to quantify that will show up in the error term and thus bias the intercept term. Finally, there are problems concerning the specification of the model as theory on the Phillips curve does not provide guidance in choosing the length of lags, the exogenous variables, or the variable definitions (Stockton and Struckmeyer, 1989). The empirical evidence below illustrates the different approaches taken by researchers.

III. LITERATURE REVIEW

In two articles, one in the *Journal of Economic Perspectives* and the other in *The Economic Report of the President 1997*, Joseph Stiglitz estimated a very simple model of the Phillips curve in order to illustrate that other influences besides the unemployment rate, play a large role in determining the inflation rate in the United States. He calculated the inflation rate as the change in the core CPI over four quarters from 1958 through 1996 (Council of Economic Advisors, 1997).[2] He then regressed the change in the core inflation rate in time t minus the core inflation rate in time t-4 against a demographically adjusted unemployment rate. He concluded that a one percentage point rise in unemployment was correlated with .6 percentage point decrease in inflation over the next year. About twenty percent of the variation in the change in the inflation rate could be explained by the unemployment rate (Stiglitz, 1997). Stiglitz (1997) predicted that by keeping the unemployment rate one percentage point below the non-accelerating inflation rate of unemployment (NAIRU), inflation would increase by .3 to .6 percentage points. The Council of Economic Advisors (1997) published an estimated natural rate of unemployment as 5.7%.

Staiger, Stock, and Watson (1997) followed a similar specification as Stiglitz and estimated a regression with the change in the rate of price inflation ($\Delta\pi$) as the dependent variable. They included several more explanatory variables including four lags of the unemployment rate and four lags of the change in the inflation rate and supply shocks (X_t) . Their unemployment variable is defined as the lagged unemployment rate (u_{t-I}) minus the natural rate of employment ($\nwarrow$). Their equation is:

$$\Delta\pi = \beta_1(u_{t-1} - \nwarrow) + \beta_2(u_{t-2} - \nwarrow)\ \gamma X_t + \upsilon_t$$

Since we do not know *a priori* the level of the natural rate of unemployment, $\nwarrow$, this equation is difficult to estimate in this form. However they factor out the $\nwarrow$, as it is constant, and define the intercept as $-(\beta_1 + \beta_2)\nwarrow$. The new specification is:

$$\Delta\pi = \mu + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \gamma X_t + \upsilon_t , \quad \text{where } \mu = -(\beta_1 + \beta_2)\nwarrow$$

The natural rate of unemployment can then be estimated as the negative of the intercept term divided by the sum of the coefficients on the lagged unemployment rates.

Using this model with a chain-weighted GDP deflator as a measure of inflation, they found that the NAIRU in 1994 was approximately 5.9% with a 95% confidence interval between 4.3 and 7.3%. In 1984, they found the NAIRU to be around 6.6 or 7% with a range between 2.9 and 8.3%, indicating that the natural rate has fallen over the past several decades. They calculated that a one percentage point increase in the unemployment rate is associated with a .44 percentage point decrease in the change in the inflation rate, a slightly smaller coefficient than estimated by Stiglitz, which is probably due to the addition of several more control variables (Staiger, Stock, and Watson, 1997).

Robert Gordon developed the Triangle Model to directly quantify the Phillips curve relationship between the inflation rate and the unemployment rate. He (1997) motivated his specification by explaining that there are three determinants of the inflation rate: inertia which occurs through sticky wages and prices; demand shocks which can be measured through deviations in output, unemployment, or capacity utilization from their trends; and finally supply shocks measured by changing energy prices, input prices, and productivity. His final specification is:

$$\pi = a(L)\pi_{t-1} + b(L)D_t + c(L)z_t + e$$

The inertia aspect is covered by $a(L)\pi_{t-1}$ which is a set of variables for the lagged inflation rate (Gordon uses 24 lags). Changes in demand are covered by $b(L)D_t$ and in this case, we can focus on the unemployment gap as the main demand variable, defined as the difference between the unemployment rate and the natural rate. Gordon (1997) also used 24 lags for the unemployment gap. The main supply shocks, $c(L)z_t$, Gordon (1982) used are changes in food and energy prices, changes in the relative price of imports, deviations in productivity growth from its trend, and dummy variables to control for Nixon's price controls and oil shocks in the 1970s.

Between the second quarter in 1955 and the second quarter in 1996, using the GDP price deflator as a measurement of inflation, Gordon (1997) found that a one percentage point increase in the unemployment gap is correlated with a .6 percentage point decrease in the inflation rate. Finally, he estimated that the current NAIRU is approximately 5.6%. Gordon (1997) concluded that his model has accurately described US inflation patterns since the 1970s: "The model has proven capable of tracking the disinflation of the early and mid-1980s, the acceleration of inflation of the late 1980s, and the subsequent deceleration of inflation in the 1990s." In contrast to the rougher estimates by Stiglitz, Staiger, Stock, and Watson (1997), Gordon (1997) believes economists can accurately predict inflation and use his regression results as a tool for policy.

IV. DATA AND EMPIRICAL SPECIFICATION

Using quarterly data between 1988 and 1998, I estimated eight different time-series regressions with the inflation rate as my dependent variable for the time period from quarter one in 1988 through the third quarter of 1998. Additionally, I estimated all eight models using two different measures of inflation, one based on the Consumer Price Index (CPI) and another based on the GDP Implicit Price Deflator (GDP). For a list of the variables, their definitions, and mean values, please see Table 1 in the Appendix. Four of the equations follow Gordon's specification which used the inflation rate, π_{CPI} and π_{GDP}, as the dependent variable. The other four equations follow Stiglitz and Staiger, Stock, and Watson's specification where the dependent variable is the change in the inflation rate. The independent variables include the unemployment rate, lags in the unemployment rate, and lags in the inflation rate to control for inflationary expectations or according to Gordon (1997), to control for inertia. Additionally, the variables for food and energy prices, productivity growth and changes in import prices are included to control for supply side shocks.

The simplest model of the Phillips curve is that proposed by Joseph Stiglitz (1997) where only the unemployment rate is used as an explanatory variable for the inflation rate. Following the specification set up by Gordon (1997), this very simplified equation is:

(1) $\pi_t = \alpha_0 + \alpha_1 UNEMP_t + \delta_t$

I then estimated an augmented version of Stiglitz's model (1997) in order to capture inflationary expectations by including the lagged inflation rate as a measure of the expected inflation rate. The equation with lagged inflation rate is:

(2) $\pi_t = \delta_0 + {}_1 UNEMPt + \delta_2\pi_{t-1} + \zeta_t$

I further augmented the equation to include supply shocks:

(3) $\pi_t = \theta_0 + \theta_1 UNEMP_t + \theta_2\pi_{t-1} + \theta_3 FE\_INF_t + \theta_4 PRODCT_t + \theta_5\ IMPORT_t + \iota_t$

Finally, I include four lags for unemployment and inflation to determine if more lags offers a better fit:

(4) $\pi_t = \mu_0 + \mu_1 UNEMP_t + \mu_2 UNEMP_{t-1} + \mu_3 UNEMP_{t-2} + \mu_4 UNEMP_{t-3} + \mu_5 UNEMP_{t-4} + \mu_6\pi_{t-1} + \mu_7\pi_{t-2} + \mu_8\pi_{t-3} + \mu_9\pi_{t-4} + \mu_{10} FE\_INFL_t + \mu_{11} PRODCT_t + \mu_{12} IMPORT_t + \xi_t$

As the Phillips curve suggests a negative trade-off between inflation and unemployment, we would expect the coefficients on UNEMP and the lagged unemployment rates to be negative as an increase in the unemployment rate should be correlated with a decrease in the inflation rate. As people expect the same rate from quarter to quarter unless there is a shock or change in policy that would alter expectations of the inflation rate, the lagged inflation rates should all be positively correlated with the inflation rate. If there is a substantial rise in the prices of food and energy or the price of imports, the costs of production would increase, causing the short run aggregate supply curve to shift left, which would result in an increase in the price level as shown in Figure 4. Therefore, FE_INF and IMPORT should be positively related to the inflation rate. Productivity growth should be negatively correlated with inflation because if workers become more productive, the aggregate supply curve would shift to the right, which increases output and lowers the price level.

For comparison, I have modified the four equations above according to the specification presented by Stiglitz, Staiger, Stock, and Watson where the change in the inflation rate is the dependent variable and the unemployment rate in the previous time period is an independent variable (instead of the current unemployment rate).

(5) $\Delta\pi_t = \beta_0 + \beta_1 UNEMP_{t-1} + \varepsilon_t$

(6) $\Delta\pi_\tau = \gamma_0 + \gamma_1 UNEMP_{t-1} + \gamma_2\Delta\pi_{t-1} + \eta_t$

(7) $\Delta\pi_t = \lambda_0 + \lambda_1 UNEMP_{t-1} + \lambda_2\Delta\pi_{t-1} + \lambda_3\Delta FE\_INF_t + \lambda_4\Delta PRODCT_t + \lambda_5\Delta IMPORT_t + \kappa_t$

(8) $\Delta\pi_t = \psi_0 + \psi_1 UNEMP_{t-1} + \psi_2 UNEMP_{t-2} + \psi_3 UNEMP_{t-3} + \psi UNEMP_{t-4} + \psi_5\Delta\pi_{t-1} + \psi_6\Delta\pi_{t-2} + \psi_7\Delta\pi_{t-3} + \psi_8\Delta\pi_{t-4} + \psi_9\Delta FE\_INF_t + \psi_0\Delta PRODCT_t + \psi_{11}\Delta IMPORT_t + \phi_t$

We would expect the variables included in equations (5), (6), (7), and (8) to have the same predicted relationships with the change in the inflation rate as explained for equations (1), (2), (3), and (4). Therefore, we would expect the lags of the unemployment rates to be negatively correlated with the change in the inflation rate. Additionally, the lags of the change in the inflation rate should be positively correlated with the change in the inflation rate as should productivity growth. Finally, the change in the food and energy prices and the change in the relative price of imports should be negatively correlated with the change in the inflation rate.

V. RESULTS

The mean values and standard errors for each variable are presented in Table 1 (in the Appendix). The average unemployment rate is 5.8% between the first quarter in 1988 and the third quarter in 1998. The mean inflation rate using the CPI as a measure of inflation is 1.43% and 1.25% when GDP is used to measure inflation. The inflation rate declined by an average .08 or .07 percentage points per year (CPI or GDP as a measure of inflation, respectively) over the past ten years. The mean values also show that food and energy prices and relative import prices have been declining since 1988. Productivity growth has been below the long run trend, however, the rate of productivity growth has been rising over the decade.

A. Results using π as the Dependent Variable:

Table 2 present the results from the first set of estimated regression equations. In examining equation (1), the simplest equation, we see that when we use the CPI as our measure of inflation, the coefficient on the unemployment rate is not statistically significant. If GDP is used to measure inflation, the coefficient on the unemployment rate is statistically significant at a 10% level, but is positive, which is the opposite of the relationship we expected theoretically, which could be due to omitted variables. Also, the fit of the regression is very poor as the adjusted R^2 value is .0169, thus the variation in UNEMP only explains 1.7% of the variation in the inflation rate from its mean.

When we add the lagged inflation rate, however, the fit of the regression improves dramatically so that the explanatory variables explain between 85 and 95% of the variation in the dependent variable. If the CPI is used to measure inflation, the lag of the inflation rate is statistically significant at the 1% level. A one percentage point increase in the inflation rate in last quarter is associated with a .9482 percentage point increase in inflation this quarter. For our estimates using GDP, both one lag of the inflation rate and the unemployment rate are statistically significant. A one percentage point increase in the unemployment rate is associated with a .03 percentage point drop in the inflation rate, and a one percentage point increase in the lagged inflation rate is correlated with a 1.03 percentage point increase in the inflation rate.

If we augment the model further to include supply shock variables (equation 3), the fit does not change dramatically. For both estimates of inflation (CPI and GDP), unemployment is no longer a significant predictor of inflation, suggesting that the significance of the unemployment variable in the earlier regressions could have occurred as it was picking up the effects of other variables that were omitted from the equation. In both equations, the lagged inflation rate is still strongly positively correlated with the inflation rate, and we see that the growth rate of food and energy prices is positive and significant at the 1% level as we expected. Thus an increase in one percentage point in the rate of food and energy inflation is correlated with a .85 or .99 percentage point increase in the inflation rate (CPI or GDP).

Finally, in equation (4) when we have included all four lags of both the unemployment and inflation rate, we see that the fit has improved further. Again, the one lag of the inflation rate is still statistically significant and positively correlated with the inflation rate. In the estimates using GDP, the significance of unemployment has returned at the 5% level, indicating that a one percentage point increase in the unemployment rate is correlated with a .18 percentage point decrease in the inflation rate. In the regression using CPI as a measure of inflation, one lag of the inflation rate, the fourth lag of the inflation rate, the food and energy measure, and imports are statistically significant and positively associated with the inflation rate as expected. Although the R^2 increased slightly with the inclusion of additional lagged variables, I conducted an F-test to determine whether adding the lags significantly helped explain the inflation rate. As the value of the F-test is below the critical value, we can conclude that the inclusion of additional lags does not significantly affect our results.

We can calculate an estimate of the natural rate of unemployment from the data in Table 2 for the period from 1988:1 through 1998:3. As explained above, the natural rate can be calculated by dividing the intercept term by the estimated coefficients on the unemployment (and lags of the unemployment) rate and multiplying by negative one. Using this formula, I find very erratic results for the natural rate of unemployment. The estimates for the natural rate of unemployment are listed in Table 2 and range from -198 to 4.73%. Obviously many of these calculations are unreasonable, probably because the estimated coefficients on $UNEMP_t$ and the lags of the unemployment rate are not statically significant.

The estimated regression equations do not predict a stable long-run Phillips curve relationship. In comparing the coefficients on $UNEMP_t$ with those found by Gordon (1997), we find a startling difference. Most of my estimates of the coefficient on $UNEMP_t$ are not statistically significant, perhaps because of omitted variable bias, incorrect specification, multicollinearity, or serial correlation. On the other hand, the lack of significance might suggest that the trade-off between unemployment and inflation does not exist in the 1990s. Perhaps Gordon (1997) found the stable relationship and coefficient of -.61 on the unemployment rate because he was estimating the Phillips curve over several decades. Whereas, if we use only the decade of the 1990s to estimate a Phillips curve, we do not see a stable relationship between unemployment and inflation.

B. Results using $\Delta\pi_t$ as the Dependent Variable

The results for equation (5), in Table 3, show that the lagged unemployment rate is statistically significant, so that a one percentage point increase in the unemployment rate in the previous quarter is correlated with a -.14 or -.12 decrease in the change in the inflation rate in the current quarter.

Although statistically significant, the adjusted R^2 value is very low indicating that the explanatory variables only explain between 6 and 10% of the variation in the change in the inflation rate, which is not surprising given that many other factors besides unemployment affect the inflation rate.

As soon as the model is augmented to include the lagged change in the inflation rate, the coefficient on $UNEMP_{t-1}$ loses significance. Once again, the lagged change in the inflation rate is highly significant and positively correlated with the current change in the inflation rate. A one percentage point increase in the change in the inflation rate last quarter will increase the current change in the inflation rate by .60 percentage points. In addition, once the lagged change in the inflation rate is added to the equation the fit improves so that the independent variables explain between 48 and 65% of the variation in the dependent variable.

Equation (7) adds the supply side factors that influence the inflation rate into the regression equation. When the CPI is used as the measure of inflation, we see that $UNEMP_{t-1}$, $\Delta\pi_{CPIt-1}$, ΔFE_INF_t, and $\Delta IMPORT_t$ are all statistically significant and positive at the 1% level as we would expect. Similar to equation (5), a one percentage point increase in the unemployment rate is correlated with a decrease in the change in the inflation by .13 percentage points. Thus a one percentage point increase in the change in the growth rate of food and energy prices over a four quarter period is associated with a .84 percentage point increase in the change in the inflation rate. If GDP is used to measure the inflation rate, only the lags of the change in the inflation rate and the change in the food and energy prices are statistically significant, although both are positive as we would predict.

Finally, equation (8) finds that only one lag of the change in the inflation rate is statistically significant using GDP as a measure of the inflation rate while the regression using the CPI shows the fourth lag of the inflation rate is statistically significant along with FE_INF, PRODCT, and IMPORT.

Surprisingly PRODCT is positively correlated with inflation, but I imagine that this is mainly due to multicollinearity, which will be discussed below. I conducted an F-test in order to test whether the addition of three extra lags improved the fit of the model, and in all cases, the fit did not improve with the additional lags.

In comparing the estimates of the NAIRU from my regression results, we find the relationship is much more stable when the change in the inflation rate is used as the dependent variable versus using the inflation rate as the dependent variable. Instead of the wide range estimated above, this specification seems to have a much more reasonable estimate of the natural rate of unemployment. The natural rate of unemployment ranges between -4.65 and 5.513%, with most of the values positive and between 4.5 and 5.5%, which is much more in keeping with the estimates found by Stiglitz, Gordon, Staiger, Stock, and Watson, suggesting that the specification using the change in the inflation rate as the dependent variable might be a superior specification.

Once again, although the coefficients for $UNEMP_{t-1}$ are slightly more significant with this alternative specification, the values for $UNEMP_{t-1}$ are around -.14, meaning that a one percentage point in the unemployment rate is associated with an decrease in the change in the inflation rate by .14 percentage points. This estimate is nowhere near the estimate made by Stiglitz of a correlation of -.6. Although faced with similar problems such as multicollinearity and serial correlation, as both specifications suggest the lack of a strong influence of unemployment on the inflation rate, we might conclude that the Phillips curve relationship does not hold in the 1990s.

C. Problems- Multicollinearity and Serial Correlation

It is important to note, however, that equation (4) might have a problem with multicollinearity which occurs when there is a linear relationship between the explanatory variables which might effect the parameter estimates. In this case, the lagged inflation rates might be linearly related as might the lagged unemployment rates. The effect of multicollinearity is to increase the standard errors of the parameter estimates. I calculated the Variance Inflation Factor, which in some cases was over 200, indicating that multicollinearity does exist between the lagged unemployment rates, therefore, the results for equations (4) and (8) should be interpreted carefully.

More importantly, there could be the problem of serial correlation, which occurs when the error terms of a regression are correlated, and can often be a problem when using time-series data. Although serial correlation does not bias our estimated regression coefficient, it does lead to an underestimate of the standard error. At the same time, the presence of serial correlation actually increases the size of the true standard error. Thus serial correlation makes it more likely that we will have statistically significant results when the true parameter estimates are insignificant. One way to determine whether the error terms are correlated is to use the Durbin Watson d Test (DW d test) which examines the residuals of the equation (Studenmund, 1997). If the results of the DW d test are 2, then there is no serial correlation. Estimates of 0 and 4 indicate positive and negative serial correlation, respectively. The values of the DW d test are listed in Table 2 and 3, and range from .065 to .681, and all fail the test at the 5% level, meaning we cannot reject the null hypothesis and thus the equations have serial correlation.

As equations (2), (3), (6), and (7) include a lag of the dependent variable the DW d test will be biased towards 2 (Studenmund, 1997), so we must use a Durbin Watson h test to examine whether there is serial correlation. The DW h test is a modified DW d test in order to account for the lagged dependent variables. If the equations exhibit serial correlation we would expect the value of the DW h test to be greater than 1.645. As illustrated in the tables, all but one of the equations exhibit positive serial correlation.

Finally, as equation (4) and (8) have multiple lags of the dependent variable, we must use the Lagrange Multiplier (LM) test in order to test for serial correlation for all eight equations. In addition, as I have a fairly small sample size of 43, the LM test will be a more accurate test of serial correlation. The Lagrange Multiplier test analyzes how well the lagged residuals explain the residuals of the original equation. If the lagged residuals explain the original residuals well, then the equation exhibits serial correlation. As shown in the tables, all of the equations using the change in the inflation rate have problems of serial correlation (Studenmund, 1997). Only equations (2) and (3) do not exhibit serial correlation. Thus, all three tests confirm our suspicion that the regressions are not the best linear unbiased estimators, as the eight regressions exhibit problems with serial correlation.

Serial correlation results from either a misspecified model such as an omitted variable, inertia, data manipulation, or the prolonged influence of shocks. In an attempt to address the autocorrelation, I estimated the model using an error correction term, which I defined as the CPI minus the unit labor cost. Once adding this term and several lags of the unit labor cost into the model, the DW statistic increased closer to 2 for all models, and did not seriously alter the results reported. However, adding this term makes estimating a NAIRU difficult and thus I have left it out.

VI. CONCLUSION

Estimating the Phillips curve is plagued with difficulties. Economists disagree about the specification of the model and which variables to include, as each specification leads to different estimates of the natural rate of unemployment. Regardless, estimating the inflation rate for the 1990s provides interesting results as there does not seem to be a stable relationship between inflation and unemployment in the 1990s. My results support the hypothesis that there is not a stable trade-off between unemployment and inflation. Thus, it seems the stable relationship between unemployment and inflation and the natural rate observed by economists such as Gordon, Stiglitz, Staiger, Stock, and Watson might be due to the long time span which they examined. Policy makers should be wary of using the Phillips curve when making decisions concerning the money supply and aggregate demand as incorrect estimates of the Phillips curve could lead to policy errors.

APPENDIX

Table 1: Variable Mean Values and Definitions

Explan. Variables	Mean	Standard Deviation	Definition
π_{CPI}[3]	1.443	.4759	the log of the CPI in time period t minus the log in the CPI in time period t-4
$\Delta\pi_{CPI}$	-.0789	.4051	the change in the inflation rate (using the CPI as a measure of inflation) in period t minus the inflation rate in period t-4
π_{GDP}	1.225	.4406	the log of the GDP deflator in time period t minus the log in the GDP deflator in time period t-4
$\Delta\pi_{GDP}$	-.0732	.2670	the change in the inflation rate (using the GDP deflator as a measure of inflation) in period t minus the inflation rate in period t-4
UNEMP	5.807	.8436	civilian unemployment rate in each quarter
FE_INF	-.0773	.1958	the CPI inflation rate minus the CPI inflation rate excluding food and energy prices
ΔFE_INF	-.0061	.3085	the difference in FE_INF in time period t minus FE_INF in time period t-4
IMPORT	-.1363	2.416	the log of the import prices in time t minus the log of import prices in time t-4
ΔIMPORT	-.5326	3.132	the difference in IMPORT in time t minus IMPORT in time t-4
PRODCT	-.5872	.4562	PRODCT is a measurement of the deviation in productivity growth from its trend. Productivity growth is the log of the nonfarm output per hour in time period t minus the log of the nonfarm output per hour in time period t-4. The deviation in productivity growth from its trend is found by subtracting the estimated long-run trend for productivity growth of 1.07 (Gordon, 1977) from the quarterly productivity growth.
ΔPRODCT	.0861	.7189	productivity growth rate in time period t minus the productivity growth rate in time period t-4
N	43		

Table 2: Regression Results with Inflation Rate as Dependent Variable

Explan. Variables	(1)π_{CPI}	(2)π_{CPI}	(3)π_{CPI}	(4)π_{CPI}	(1)π_{GDP}	(2)π_{GDP}	(3)π_{GDP}	(4)π_{GDP}
INTER-CEPT	1.264	.2301	.0685	-.2911	.6158	.1118	.0194	-.1190
	(.5160)	(.2098)	(.1912)	(.2761)	(.4688)	(.1085)	(.1141)	(.1449)
$UNEMP_t$	.0311	-.0314	.0358	.0515	.1049*	-.0296*	-.0042	-.1780**
	(.0880)	(.0341)	(.0366)	(.1574)	(.0799)	(.0189)	(.0225)	(.0977)
$UNEMP_{t-1}$				-.1761				.1193
				(.2484)				(.1615)
$UNEMP_{t-2}$				.1278				.1137
				(.2634)				(.1718)
$UNEMP_{t-3}$				-.0886				-.1817
				(.2755)				(.1747)
$UNEMP_{t-4}$				.1470				.1261
				(.1773)				(.1070)
πCPI_{t-1}		.9482***	.8532***	.5479***				
πGDP_{t-1}		(.0617)	(.0648)	(.1786)		1.03***	.987***	1.193***
						(.0377)	(.0418)	(.1985)
πCPI_{t-2}				.0684				
πGDP_{t-2}				(.2079)				-.3126
								(.2934)
πCPI_{t-3}				.1613				
πGDP_{t-3}				(.1928)				.0133
								(.2917)
πCPI_{t-4}				.2141*				
πGDP_{t-4}				(.1495)				.1900
								(.2164)
FE_INF_t			.5279***	.7822***			.0691	.1011
			(.1549)	(.1818)			(.0914)	(.0976)
$IMPORT_t$			.0201	.0262*			.0122	.0112
			(.0186)	(.0200)			(.0110)	(.0116)
PRODCTt			.0773	.0956			-.0098	.0167
			(.0876)	(.0912)			(.0525)	(.0562)
Adj-R^2	-.0213	.8484	.8835	.8907	.0169	.9488	.9512	.9521
Estimated Natural Rate	-40.64	7.328	-1.91	4.726	-5.870	3.996	4.629	-198.3
DW d-test	.145★				.065★			
DW h-test		.9426	1.876★			2.233★	1.773★	
LM		.4644	3.668	30.42★		4.924★	3.565	20.80★
F-Test				1.575				1.282

Standard Errors in Parentheses, * Significant at the 10% level for one-sided test, ** Significant at the 5% level for one-sided test, *** Significant at the 1% level for one-sided test , ★ Indicates Positive Serial Correlation (using one-sided test at 5% level)

Table 3: Regression Results with Change in Inflation Rate as Dependent Variable

Explan. Variables	(5) $\Delta\pi_{CPI}$	(6)$\Delta\pi_{CPI}$	(7)$\Delta\pi_{CPI}$	(8)$\Delta\pi_{CPI}$	(5)$\Delta\pi_{GDP}$	(6)$\Delta\pi_{GDP}$	(7) $\Delta\pi_{GDP}$	(8) $\Delta\pi_{GDP}$
INTER-CEPT	.7376	.1948	.7132	.7354	.5975	-.0085	-.1108	.0355
	(.4369)	(.3383)	(.1861)	(.2173)	(.2809)	(.1894)	(.1864)	(.2431)
$UNEMP_{t-1}$	-.140**	-.0427	-.1311***	.0836	-.115**	-.0031	-.0238	-.0689
	(.0741)	(.0577)	(.0316)	(.1397)	(.0477)	(.0356)	(.0320)	(.1538)
$UNEMP_{t-2}$				-.0897				.0798
				(.2426)				(.2729)
$UNEMP_{t-3}$				-.2308				-.1755
				(.2511)				(.2737)
$UNEMP_{t-4}$				.1035				.1519
				(.1477)				(.1585)
$\Delta\pi CPI_{t-1}$		.598***	.1810***	.0531				
		(.1026)	(.0700)	(.1097)				
$\Delta\pi GDP_{t-1}$						.810***	.6781***	.873***
						(.0992)	(.1063)	(.1965)
$\Delta\pi CPI_{t-2}$				.0201				
				(.1125)				
$\Delta\pi GDP_{t-2}$								-.1519
								(.2535)
$\Delta\pi CPI_{t-3}$				-.0012				
				(.1027)				
$\Delta\pi GDP_{t-3}$								-.0991
								(.2525)
$\Delta\pi CPI_{t-4}$				.1498**				
				(.0824)				
$\Delta\pi GDP_{t-4}$								.0080
								(.2058)
ΔFE_INF_t			.8425***	.9985***			.1376*	.0873
			(.0929)	(.1134)			(.0876)	(.0978)
$\Delta IMPORT_t$			.0372***	.0575***			.0007	-.0039
			(.0140)	(.0156)			(.0128)	(.0149)
$\Delta PRODCT_t$			.0658	.0856*			-.0562	-.0386
			(.0537)	(.0536)			(.0528)	(.0605)
Adj-R^2	.0574	.4777	.8580	.8696	.1028	.6549	.6887	.6650
Estimated Natural Rate	5.269	4.562	5.440	5.513	5.196	-2.742	-4.655	2.795
DW d-test	.681★				.390★			
DW h-test		2.296★	3.780★			2.733★	2.579★	
LM		5.345★	13.65★	16.79★		6.175★	4.691★	31.79★
F-test				1.497				.5452

Standard Errors in Parentheses, * Significant at the 10% level for one-sided test, ** Significant at the 5% level for one-sided test, *** Significant at the 1% level for one-sided test , ★ Indicates Positive Serial Correlation (using one-sided test at 5% level)

FOOTNOTES

[1] Cyclical unemployment is the difference between the natural rate of unemployment (when output and employment are ate full-employment) and the unemployment rate (Abel and Bernanke, 1998).

[2] Core inflation is usually defined to exclude energy and food prices.

[3] All data taken from the Federal Reserve Board's web page on 9 April 1999, http://www.stls.frb.org/fred/index.html except for the data on import prices which was gathered from select volumes of *International Financial Statistics*.

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