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US Growth And Inflation

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ABSTRACT

This paper tests the relation between inflation and growth in the US. This relation is negative and statistically significant even with a monthly frequency. Moreover, the impact is higher with quarterly data, relative to annual data, and higher with monthly data relative to quarterly data. The relation remains robust (1) with IV (2SLS) estimation, (2) when inflation is divided into positive and negative components, (3) when it is divided into expected and unexpected components, and (4) when the applied model is an expectations-augmented Phillips curve. Although the paper argues that the theory that should explain this negative relation is the demand for real balances, the evidence is also consistent with a simple bivariate association.

Keywords: growth, inflation, deflation, expected and unexpected inflation, supply shocks, demand for real balances, 2SLS.

1 INTRODUCTION

Policy makers, especially those in the monetary realm, espouse the idea that low inflation and rapid real growth are macroeconomic goals that should be privileged. Originally in the late 1950s the stylized facts were that the two are in conflict. However for about the last 20 years the statistical evidence has swayed into the opposite direction. There is a growing body of empirical research that finds that the two goals are and can be achieved simultaneously at least in the long run. This paper conforms to this recent literature. However, it has additional contributions. First, instead of using panel data, the analysis is restricted to the US. This allows the testing of many hypotheses that cannot be tested with panel data. Second, the frequency of the observations is monthly. The results show that the negative relation between inflation and growth is not restricted to the long run, i.e. not restricted to yearly or 5-year averages, but is also a feature of short time spans. Moreover, the study uncovers that the impact of inflation on real growth is higher with quarterly data relative to yearly data, and higher with monthly data relative to quarterly data. Third, deflation does not produce any additional output benefits or costs. Fourth, both anticipated and unanticipated inflation are negatively correlated with growth. Fifth, IV estimation with 2SLS shows that the negative relation is not due to simultaneity bias or reverse causation. Sixth, since the 1970s witnessed clearly negative supply shocks, separating the 1970s from the whole sample does not weaken the relation. Seventh, stating the model as an expectations-augmented Phillips curve does not change the negative sign of the relation. Eighth, and contrary to most of the literature which uses *ad hoc* conditioning variables in the regressions, this paper argues that the money demand equation can explain the relation in a neat theoretical way. Unfortunately further scrutiny finds that this theoretical model is not superior to a model where the only two variables are inflation and growth.

The paper is organized as follows. The second section discusses the theoretical underpinnings of the relation between inflation and growth. The question that is asked is how does theory explain this relation, and particularly the negative relation? The third section is a look on the empirical literature. This section starts from the Phillips curve of the late 1950s and ends with the most recent research on the topic. In the fourth section the hypotheses stated here are tested empirically and interpreted. The last section is a conclusion.

2 THE THEORY

A negative relation between output and the price level arises when there is a movement along the Aggregate Demand (AD) curve. The derivation of the AD curve is from the equation of exchange, which is at the basis of the quantity theory:

$$MV = PY \quad (1)$$

If money supply (M) does not change and velocity (V) is constant, then a rise in real output (Y) occurs with a fall in the price level (P) in order to maintain equality. A movement along the AD curve can only come about if the Aggregate Supply (AS) curve shifts. Mishkin (2004) enumerates four factors that shift the AS to the left resulting in a higher price level and lower output. If output is above the natural rate there is increased pressure in the labor market which raises wages and production costs and shifts the AS curve to the left. This is described in the press as overheating of the economy. If labor expects prices to go up wages are pushed up now resulting in higher production costs and a shift of the AS curve to the left. In this case expected inflation has a non-neutral and negative relation with output. If a wage push is imposed by labor unions, production costs are higher, and this shifts the AS curve to the left. Finally, a negative supply shock, like oil price increases or volatility in the commodity markets, shifts the AS curve to the left.

Friedman (1968) and Phelps (1968) have hypothesized that there is no long run trade-off between inflation and unemployment (or growth). Friedman (1977) went as far as to argue that in some cases a higher inflation rate, which occurs with higher volatility of inflation, affects detrimentally growth. Normally, in the long run expected inflation is equal to actual inflation and the rate of unemployment is set at its natural level. This is called the expectations-augmented Phillips curve. Therefore in the long run nominal variables, like inflation, have no effect, but may have an adverse effect, on real variables, like the unemployment rate or growth.

Lucas (1972, 1973, 1975) extended the theory of inflation in his islands model by assuming that firms misperceive higher unanticipated prices as being higher relative prices, thereby boosting supply. Therefore, in the Lucas supply function there is a positive effect of unexpected inflation on growth. Lucas recognized a role for unanticipated inflation, but not for anticipated inflation, which he considered to be neutral. New Keynesians believe that inflation expectations and money supply changes are non-neutral, and particularly that higher expected inflation, induced by a higher expected money supply level, is expansionary, resulting in a shift of the AD curve to the right, which produces a higher output. This is a justification made by New Keynesians to the Phillips curve which predicts that there is a trade-off between higher inflation and unemployment (or growth). However New Keynesians admit with the New Classical economists, like Lucas, that higher unexpected inflation is expansionary.

Paul *et al.* (1997) list other theories of inflation while stressing two-way causality and conflicting effects. In a Keynesian world with sluggish real wages, inflation promotes growth by redistributing income from workers to entrepreneurs with higher propensities to save and invest. In a New Classical world with flexible prices inflation imposes a tax on money balances, which, when spent by the government, gives a boost to growth. High inflation is usually accompanied with more variable inflation which raises the cost and riskiness of capital, and adversely affects resource allocation.

Motley (1998) lists many reasons why inflation is welfare-decreasing. Inflation distorts price signals. In this respect it is found that the more developed the financial system the more sensitive this system is to inflation (Burdekin *et al*., 1994). Inflation introduces pecuniary costs like menu and search costs. Other social costs arise because inflation affects different economic agents differently. Inflation causes income tax bracket creep if indexation is incomplete. Inflation gives incentives to persons to devote their talents to fight its bad effects instead of them devoting their efforts for productive endeavors. Inflation affects saving and investment through the variability and lack of precision of real returns which become difficult to forecast, making long term projects less desirable. In turn lower long term investment leads to slower growth.

Gillman *et al.* (2004) present a model where the inflation tax causes substitution to leisure away from employment, thus reducing growth. They find empirical evidence in support of this hypothesis.

A theoretical model for inflation is the one proposed by Fama (1981). See also Fry (1995) and more recently Bachmeier and Swanson (2005). It is based on the classical theory of the demand for real balances:

$$Log\left(\frac{M}{P}\right) = \alpha_0 + \alpha_1 Log(Y) - \alpha_2 i \quad where\ \alpha_1 > 0\ \ and\ \ \alpha_2 > 0 \tag{2}$$

where M is money supply, P the price level, Y income, and i the interest rate. Taking first-differences of the variables one gets:

$$\left(\frac{\Delta(M)}{M}\right) - \left(\frac{\Delta(P)}{P}\right) = \alpha_0 + \alpha_1\left(\frac{\Delta(Y)}{Y}\right) - \alpha_2(\Delta(i)) \tag{3}$$

or

$$\left(\frac{\Delta(P)}{P}\right) = -\alpha_0 - \alpha_1\left(\frac{\Delta(Y)}{Y}\right) + \alpha_2(\Delta(i)) + \alpha_3\left(\frac{\Delta(M)}{M}\right) \qquad where \qquad \alpha_3 > 0 \tag{4}$$

or

$$\left(\frac{\Delta(Y)}{Y}\right) = \beta_0 - \beta_1\left(\frac{\Delta(P)}{P}\right) + \beta_2\left(\frac{\Delta(M)}{M}\right) + \beta_3(\Delta(i)) \ \ where\ \ \beta_1 > 0\ \beta_2 > 0\ and\ \beta_3 > 0 \tag{5}$$

Equation (4) states that the inflation rate is negatively related to the real growth in income, is positively related to the change in a given interest rate, and is positively related to the growth in the money supply. Equation (4) shows that the negative relation between inflation and real growth should be augmented by two variables: the change in a given interest rate, and the percent change in the money supply. Otherwise, the relation between inflation and real growth will suffer from the bias of omitted relevant variables. Equation (4) has the advantage of relying on a widely accepted theory of money demand, and does not include variables that are thought to explain the inflation rate in an *ad hoc* fashion. Similarly, equation (5) augments the relation between real growth and inflation with two additional variables: money growth and the change in a given interest rate. In the empirical section it is found that, while equation (4) holds quite well, estimation of equation (5) is more problematic: only inflation enters statistically significantly. That is why the general conclusion of this paper is that there is not enough proof that the money demand equation explains all the facts. A simple bivariate relation between growth as the dependent variable and inflation as the independent variable is as well supported as equation (4) is.

3 THE EMPIRICAL LITERATURE

This section lists some of the main ideas in the empirical literature pertaining to the Phillips curve and the relation between inflation and growth. It is very rare to find in one place these two strands of the literature surveyed together.

Some of the issues involved for the Phillips curve are the following. Is the curve linear? Is it in levels or in first-differences? What variable should replace unemployment? What variable should measure price changes? Does it hold always or only for specific time periods? Are dynamics necessary? What are the variables to include in the relation? Which model to select if the empirical results are not consistent with each other?

Phillips (1958) found a negative, non-linear, and statistically significant relation between the unemployment level, as an independent variable, and the percent change in nominal wages as a dependent variable. As unemployment falls, it was reasoned, demand for labor picks up as firms compete for employees. Since there are few unemployed people, wages are bid up. According to Pressman (2006, p. 248) it is Samuelson and Solow (1960) who coined and popularized the phrase ‘Phillips Curve.’ Friedman (1977) criticized Phillips’s transmission mechanism by arguing rightly that when unemployment falls, and wages are bid up, real wages and not nominal wages are higher.

Later on the Phillips curve was specified differently. Instead of the percent change in nominal wages, inflation was used, keeping the unemployment rate as is (Friedman, 1977). Friedman described three stages for the trade-off: short run, long run, and "institutional". In the short run the Phillips curve holds and can be used for fine-tuning the economy. In the long run the trade-off disappears, and the relation is vertical starting at the natural rate of unemployment. The third stage is an upward sloping curve that remains upward sloping until economic and institutional adaptations to chronic inflation occur. The short run trade-off includes expected inflation, and when inflation expectations catch up with actual inflation the curve shifts upward. The original formulation of Phillips did not have an expected inflation variable. That's why the new relation was called expectations-augmented Phillips curve. Inflation expectations were initially taken to follow an adaptive process, i.e. a process that relies on past values of inflation, and later came to be taken according to rational expectations. At that time there was a controversy on whether the sum of the coefficients on lagged inflation in the adaptive process should add up to one. When rational expectations are assumed the coefficient on expected inflation should definitely be one.

Fair (1984) uses a more elaborate model, that includes dynamics, and he finds that the trade-off is in levels and not in first-differences, meaning that unemployment affects the price level, and not the inflation rate. However, Gordon (1984, p. 87) in a comment on Fair says that Fair's model includes "a rate-of-change equation struggling to get out, since in both the price and wage equations the coefficient on the lagged dependent variable is greater than 0.9". Gordon (1990) defines a model that consists of inertia, hysteresis and level effects as explanatory variables, and the percent change in nominal wages, real wages, or inflation as separate dependent variables. Inertia is due to lag effects from the past of the dependent variable. Hysteresis refers to an unstable natural rate of unemployment. The level effect is the relation of interest for the trade-off. As an alternative to the unemployment variable, some economists take the income gap to measure excess demand.

Atkeson and Ohanian (2001) argue and present evidence that all the specifications of the Phillips curve result in a forecast of inflation that is inferior to a naïve forecast of inflation, where future inflation is predicted by past inflation. Lansing (2002) provides a summary of the study of Atkeson and Ohanian (2001).

It has been found that a generalized Phillips curve is instrumental in predicting inflation relatively well (Stock and Watson, 1999).[1] Bachmeier and Swanson (2005, p. 577) finds that the "Phillips curve forecasts encompass the quantity theory VEC forecasts at short horizons," while at horizons of 2 to 3 years there is a superior predictive power for the quantity theory, especially if the cointegration vectors of the quantity theory are imposed and not estimated.

Niskanen and Reynolds (2002) show an upward sloping Phillips curve where the annual unemployment rate is predicted by the annual inflation rate lagged twice during the period 1961-2001. The authors explain this feature by imperfect inflation indexation, confusion of market agents about relative prices, and the policy reaction of the monetary authorities restricting bank credit after a rise in inflation. Therefore, leading inflation provides support to the original downward sloping Phillips curve, while lagging inflation produces an upward sloping Phillips curve.

Another example of an upward sloping curve in the literature is the finding by Lee *et al.* (2005) that the slope of the Phillips curve depends on the type of shocks. A regime with dominant demand shocks produces a trade-off between unemployment and inflation, while a regime with dominant supply shocks reverses the trade-off.

Recently Schreiber and Wolters (2007) and Russell and Banerjee (2008) have used cointegration analysis to relate inflation to the unemployment rate. The first two studied Germany, while the second two studied the US. Their results are conflicting. The first two find a trade-off, while the second two find an upward-sloping Phillips curve. There are two disturbing features about the results of Schreiber and Wolters (2007): the natural rate of unemployment is measured to be 12%, and the adjustment of inflation to the long run is quasi instantaneous, taking between 0.74 to 1.12 quarters given that their data frequency is quarterly.

Equation (4) is estimated in Fama (1981). As expected the coefficients on the percent change of the current, lagged and lead industrial production, which proxies for income, are negative and statistically significant. Also as

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[1] A generalized Phillips curve is one that includes lags of the dependent variable and lags of the independent variables.

expected the coefficients on the current and lagged growth of the monetary base are positive and statistically significant. Fama (1981) finds, however, that the change in the interest rate does not have a marginal and reliable explanatory power. Fry (1995, pp. 207-208) estimates equation (4) for Turkey and he obtains statistically significant coefficients having the correct signs. Fama (1981) and Fry (1995) stand alone in the literature in estimating equation (4). The majority of papers on the relation between inflation and growth do not follow Fama's and Fry's applications of the theoretical model of money demand.

Alexander (1990), who has pioneered the research on the subject, uses *ad hoc* variables in his panel regressions, like the growth rate of government consumption and the growth rate of the budget deficit, both as a proportion of GDP. The coefficient on the inflation variable predicts that a 1% increase in inflation leads approximately to a 0.2% fall in growth.

Burdekin *et al.* (1994) estimate also a panel regression with the inflation rate, the change in the inflation rate, a time trend, and oil prices as the independent variables. They argue that the change in the inflation rate should pick up a short run Phillips curve effect. This assumes implicitly that the inflation rate follows a random walk so that the change in inflation is unexpected inflation. They document the first non-linearity in the data: the magnitude of the effect of inflation on growth is larger for industrial countries than for developing countries. This effect ranges between -0.123 and -0.232.

Alexander (1997) starts from a model of income growth as a function of the growth of factor inputs (labor and capital), and hypothesizes that the technical change is a function of the inflation rate. He finds that both inflation and its first-difference are significantly negatively related to growth. The estimates of the impact of the inflation rate ranges between -0.12 to -0.19. Motley (1998), like Alexander (1997), uses a growth of inputs model, and he is unable to reject a negative relation between the Solow's residual in growth theory and inflation. Shelley and Wallace (2004) in a study on Mexico find a positive and significant relation between unexpected inflation and growth, contrary to Alexander (1997).

Paul *et al.* (1997) test the direction of causality between inflation and growth. They find disparate results. However they conclude that developed countries stand to benefit more from reducing inflation, a fact consistent with the non-linearity identified above.

Ghosh and Phillips (1998a, 1998b) discover two other nonlinearities. At very low inflation rates inflation and growth are *positively* related. At higher inflation rates the relation is negative and convex, meaning that the negative effect is stronger with a change in inflation from 10% to 20% than with a change from 40% to 50%. They also find evidence that disinflation is costly especially at low inflation rates. Judson and Orphanides (1999) also study annual panel data. They find that the negative relation between inflation and growth is robust even with the inclusion of volatility of inflation, but this relation breaks down under double-digit inflation.

Kim and Willett (2000) are able to reject the view that the negative relation between inflation and growth is due to the years when a negative oil supply shock affected the markets. They estimate an effect between -0.0776 and -0.2007 for G-7 countries.

Khan and Senhadji (2001), like Ghosh and Phillips (1998a, 1998b), find a threshold below which inflation is not related to growth. While Ghosh and Phillips (1998a, 1998b) identify a threshold of 2.5% Khan and Senhadji (2001) find a threshold of 1% for industrial countries and 11% for developing countries. Burdekin *et al.* (2004) estimate the coefficient on the inflation to be -0.21 for industrial countries, and they also find that the inflation threshold rate is within single digits of inflation. This threshold is around 8% for industrial countries and 3% for developing countries, contrary to Khan and Senhadji (2001) who find a higher threshold for developing countries. Vaona and Schiavo (2007) estimate a threshold inflation rate of 12% for both developed and developing countries. However the threshold is not significant for developing countries alone, while it remains the same for developed countries. This is evidence in support of Burdekin *et al.* (2004) but not of Khan and Senhadji (2001).

Black *et al.* (2001) find for the US that the relation between inflation and growth is positive when there is a downward trend in inflation, and negative when there is an upward trend. Valdovinos (2003) uncovers that the negative relation between inflation and growth is significant only for the long run, after filtering the data.

Finally, Erbaykal and Okuyan (2008) test the relation for Turkey. They use quarterly data, whereas the literature has invariably used annual data, and they test the relation for one single country, whereas the literature has used panel data. They find a statistically negative relation between inflation and growth even with quarterly data. Azar (2008) finds also a statistically significant negative relation for the US using quarterly data. Using five different specifications Azar (2008) finds consistently that a 1% increase in inflation, e.g. from 3% to 4%, predicts a 0.3% decrease in real growth. This is equivalent to an elasticity of -0.01033. This compares with an elasticity of -0.0108 for the full sample (Ghosh and Phillips, 1998b, p. 682, Table 2) and of -0.00923 for industrial countries (Khan and Senhadji, 2001, p. 18, Table 6).

Table 1
Regressions with $\Delta(Log(Y))$ as the dependent variable where Y is real personal disposable income.
The conditional variance is modeled as ARCH(1).

Conditional mean equation

Constant	0.00460 (10.9467)	0.00447 (9.1486)	0.00469 (10.0501)
$\Delta(Log(P))$ or actual inflation rate	-0.42399 (-4.4644)		
Expected inflation rate		-0.38072 (-2.8266)	
Unexpected inflation rate		-0.46210 (-4.1550)	
Positive inflation rate			-0.44577 (-4.2162)
Negative inflation rate			-0.25450 (-0.4291)

Conditional variance equation

constant	$3.20\ 10^{-5}$ (31.1143)	$3.18\ 10^{-5}$ (29.1003)	$3.19\ 10^{-5}$ (30.3353)
ARCH(1)	0.46418 (9.3291)	0.47750 (8.8414)	0.46618 (9.2717)

Tests with actual probabilities

Ho: slopes are equal		0.6048	0.7625

Regression econometric diagnostics

$\overline{R}^2$	0.01704	0.01528	0.01554
Log likelihood	2156.124	2156.230	2156.250
Actual probability of the Ljung-Box Q-statistic for lag k on the standardized residuals	k=6: 0.148 k=12: 0.189 k=24: 0.386	k=6: 0.149 k=12: 0.197 k=24: 0.396	k=6: 0.140 k=12: 0.184 k=24: 0.369
Actual probability of the Ljung-Box Q-statistic for lag k on the squares of the standardized residuals	k=6: 0.963 k=12: 0.870 k=24: 0.999	k=6: 0.967 k=12: 0.885 k=24: 0.999	k=6: 0.963 k=12: 0.876 k=24: 0.999

Notes: t-statistics in parenthesis. The expected inflation rate is the fitted value, and the unexpected inflation is the residual, of the AR(12) process of inflation with first-order serial correlation of the residuals (see Table 5, column 2). The positive inflation rate is equal to the actual inflation rate if inflation is positive and zero otherwise. The negative inflation rate is equal to the actual inflation rate if the inflation rate is negative and zero otherwise. The samples span the period from 1959:01 to 2008:10, making an adjusted total of 597 monthly observations.

4 THE EMPIRICAL RESULTS

All the data statistics are monthly and are taken from the web page of the Federal Reserve Bank of Saint Louis. These are: real personal disposable income, the consumer price index, the Baa corporate bond yield, and currency in circulation. The common samples are from 1959:01 to 2008:10. The CPI is available from 1948:01 to 2008:10. The choice of real disposable income as a basis for measuring growth and the choice of currency as a money stock is due to data availability with a monthly frequency.

The data are checked for stationarity. The Augmented Dickey-Fuller (1979) test and the Phillips and Perron (1988) test reject non-stationarity for the first-difference of the log of all the variables, except the Baa yield, at significance levels below 0.01. The hypothesis of non-stationarity for the first difference of the Baa yield is also rejected at significance levels below 0.001. The Ng and Perron (2001) test gives similar results only for the change of the log of real disposable income and the first-difference of the Baa corporate bond yield. The tests fail to reject non-stationarity for the other two series at significance levels higher than 10%. The KPSS (1992) test fails to reject stationarity only for the first difference of the Baa corporate bond yields. The null of stationarity is rejected for the other three variables at significance levels below 5%. The decision is taken to assume that the log relatives of real disposable income, of the CPI, and of currency are all stationary, and that the change in the Baa corporate bond yield is also stationary.

The first model to be estimated is the continuously compounded change in personal real disposable income $\Delta(Log(Y))$ as a function of the continuously compounded change in the inflation rate $\Delta(Log(P))$ (Table 1, column 2). The coefficient on inflation is -0.424 with a t-statistic of -4.464. Therefore the impact of inflation is strong, and stronger than with quarterly data (around -0.3), and much stronger than with annual data (around -0.2).[2]

In the same table (Table 1, column 3) $\Delta(Log(P))$ is divided into a predicted component and an unpredictable component with the use of an ARIMA specification (see Table 5, column 2). Both expected and unexpected inflation are negatively related to real growth and their t-statistics are highly significant. The hypothesis that the two impacts are equal fails to be rejected with an actual probability of 0.6048, although the coefficient on the unexpected component is higher in absolute values. These results run against the theory that unexpected inflation is expansionary like in a Lucas-type supply function. Unexpected inflation redistributes wealth from lenders to borrowers, and increases the inflation tax unexpectedly. As a major debtor, the government stands to gain from both the down-valuation of its debt and the higher inflation tax. Despite the fact that the government might increase spending and boost aggregate demand, it seems that on net the economy loses. Since the wealthy are the bond-holders, and since they are hurt both because they are private lenders and public lenders, they will curtail investment and counterbalance the government stimulus.

The predictions of New Keynesians of the non-neutrality of expected money supply changes that drive expected inflation are also discredited because the effect of higher expected inflation is not expansionary. The theory that wages are bid up and, as a result, production costs are higher with higher expected inflation, is corroborated.

Again in the same table (Table 1, column 4) the inflation rate is divided into positive and negative components. Positive inflation has a statistically significant impact, with a coefficient of -0.446, while negative inflation has a statistically insignificant coefficient. Therefore deflation produces neither additional costs nor additional benefits. This runs contrary to the evidence in parts of the literature that below certain thresholds inflation is positively related to growth.

The three regressions in Table 1 are estimated with an ARCH(1) specification of the conditional variance. The standardized residuals are computed. These are the ratios of the residuals unto the conditional standard deviations. Higher order serial correlation and further conditional heteroscedasticity are rejected. Moreover, one can

[2] Using growth in per capita disposable income instead of disposable income gives very similar regression results. These results are available from the author for those who wish to consult them.

invoke the Central Limit Theorem for asymptotic normality of the standardized residuals because the sample sizes are large. Therefore the econometric diagnostics are all favorable.

Table 2 presents the 2SLS Instrumental-Variable regression between inflation and real growth. The coefficient on the inflation rate is -0.354 and is statistically significant (t-statistic: -3.819). This is evidence that proper treatment of endogeneity does not change much the results. Hence the hypothesis that inflation *causes* a fall in real growth cannot be rejected. This is consistent with most of the literature on the topic. The diagnostic statistics on higher order serial correlation reject further serial correlation. However the diagnostic statistics on conditional heteroscedasticity fail to reject heteroscedasticity.

Table 2
Regression with $\Delta(Log(Y))$ as the dependent variable where Y is real personal disposable income. $\Delta(Log(P))$ is the continuously compounded inflation rate. T-statistics are in parenthesis. The 2SLS estimation is carried out with four lags of $\Delta(Log(Y))$, four lags of $\Delta(Log(P))$, and a trend as instruments. The adjusted number of monthly observations is 593.

Constant	0.00394 (10.6933)
$\Delta(Log(P))$	-0.35372 (-3.8190)
AR(1)	0.35695 (2.3963)
MA(1)	-0.59944 (-4.5108)
$\overline{R}^2$	0.08145
Actual probability of the Ljung-Box Q-statistic for lag k on the actual residuals	k=6: 0.280 k=12: 0.337 k=24: 0.523
Actual probability of the Ljung-Box Q-statistic for lag k on the squares of the actual residuals	k=6: 0.000 k=12: 0.000 k=24: 0.003

Table 3
Regression with $\Delta(Log(Y))$ as the dependent variable where Y is real personal disposable income. $\Delta(Log(P))$ is the continuously compounded inflation rate. T-statistics are in parenthesis. The regression is with an ARCH(1) model for the conditional variance. The sample size consists of 597 monthly observations.

Conditional mean equation

D1 = 1 for 1971:9 to 1979:9, = 0 otherwise	0.00611 (4.7735)
D2 = 0 for 1971:9 to 1979:9, = 1 otherwise	0.00444 (9.7891)
D1* $\Delta(Log(P))$	-0.60921 (-2.7541)
D2* $\Delta(Log(P))$	-0.39825 (-3.7126)

Conditional variance equation

constant	$3.22\ 10^{-5}$ (31.1796)
ARCH(1)	0.44936 (8.5945)

Tests with actual probabilities

Coefficient on D1 = coefficient on D2	0.2132
Coefficients on interactive variables (i.e. slopes) are equal	0.3875

Regression econometric diagnostics

$\overline{R}^2$	0.02282
Log likelihood	2156.922
Actual probability of the Ljung-Box Q-statistic for lag k on the standardized residuals	k=6: 0.109 k=12: 0.191 k=24: 0.393
Actual probability of the Ljung-Box Q-statistic for lag k on the squares of the standardized residuals	k=6: 0.967 k=12: 0.877 k=24: 0.999

In Table 3 two historic dummies are defined: one of them is for the period 1971:9 to 1979:9, where the dummy takes the value 1 and zero otherwise. The second dummy is equal to one minus the first dummy. These two dummies are included as shift and interactive parameters. The purpose is to test whether the results are driven by the period when the US witnessed negative supply shocks (1971:9 to 1979:9). The regression is estimated with an ARCH(1) specification for the conditional variance. Although the coefficients on the shift and interactive variables for the first dummy are higher (in absolute terms) than those on the second dummy, the two tests of equality of shift coefficients and of equality of interactive coefficients fail to be rejected with actual probabilities of 0.213 and 0.388 respectively. Therefore the conclusion is that the stagflation of the 1970s did not confound the results. The regression diagnostics are all favorable. This means that the regression is likely to be well specified.

Table 4 gives the empirical results by differentiating between expected and unexpected inflation and by estimating equation (5). Expected inflation is the fitted values of an ARIMA process on inflation (see Table 5, 2nd column), and unexpected inflation is the residuals. The coefficients on both variables are negative and statistically significant. The coefficient on expected inflation is -0.433 and the coefficient on unexpected inflation is -0.482. These correspond to estimates of coefficients of -0.381 and -0.462 in Table 1 (3rd column). The test that these two coefficient estimates in Table 4 are equal fails to be rejected with an actual probability of 0.762. Therefore, as noted above, the impact of expected inflation is similar to the impact of unexpected inflation, which is surprising. See the discussion above about Table 1.

Table 4

Regression with $\Delta(Log(Y))$ as the dependent variable where Y is real personal disposable income. $\Delta(Log(P))$ is the continuously compounded inflation rate. T-statistics are in parenthesis. The regression is with an ARCH(1) model for the conditional variance. The variables bb and CC are respectively the Baa corporate bond yield in percent per annum, and currency in circulation. The sample size consists of 597 monthly observations.

Conditional mean equation

Constant	0.00461 (8.9933)
Expected inflation	-0.43308 (-3.1752)
Unexpected inflation	-0.48192 (-4.3095)
$\Delta(bb/1200)$	2.1228 (1.3906)
$\Delta(Log(CC))$	0.00762 (0.1765)

Conditional variance equation

constant	$3.16\ 10^{-5}$ (26.9698)
ARCH(1)	0.48106 (8.4966)

Tests with actual probabilities

Coefficient on expected inflation = coefficient on unexpected inflation	0.7623
Coefficient on $\Delta(bb/1200)$ = coefficient on $\Delta(Log(CC))$ = 0	0.3684

Regression econometric diagnostics

$\bar{R}^2$	0.01559
Log likelihood	2157.336
Actual probability of the Ljung-Box Q-statistic for lag k on the standardized residuals	k=6: 0.118 k=12: 0.170 k=24: 0.390
Actual probability of the Ljung-Box Q-statistic for lag k on the squares of the standardized residuals	k=6: 0.970 k=12: 0.886 k=24: 0.999

The regression includes two additional variables: the change in the Baa corporate bond yield and the change in the log of currency in circulation. Although the theory is straightforward the coefficients on these last two variables are not statistically significant. The hypothesis test that these two coefficients are equal and equal to zero is not rejected with an actual probability of 0.368.

The regression is carried out with an ARCH(1) specification of the conditional variance. The econometric diagnostics on higher order serial correlation and on further conditional heteroscedasticity are favorable. All the actual probabilities are higher than 10%. Finally one can invoke the Central Limit Theorem for asymptotic normality because the sample is large.

Table 5

Regressions with $\Delta(Log(P))$, the continuously compounded inflation rate, as a dependent variable. The conditional variance is modeled as IGARCH(1,1). T-statistics are in parenthesis. The sample sizes consist respectively of 717, 597, 596, and 597 monthly observations.

Conditional mean equation				
Constant	0.00031 (5.1997)	0.00051 (7.3525)	0.00035 (4.7950)	0.000081 (1.1592)
$\Delta(Log(Y))$ Short run Long run		-0.02362 -0.16337 (-3.4911) (-3.1266)	-0.03401 -0.27199 (-4.6066) (-4.1966)	-0.02262 (-3.6660)
Expected inflation				1.00411 (48.2433)
$\Delta(bb/1200)$ Short run Long run			1.68506 13.47734 (5.6970) (4.8375)	
$\Delta(Log(CC))$ Short run Long run			0.01982 0.15856 (1.9765) (2.0200)	
Sum of the coefficients on the 12 lags of $\Delta(Log(P))$	0.88778 (50.0242)	0.85545 (43.4126)	0.87497 (58.1106)	
AR(1)	-0.42853 (-2.4589)		-0.62325 (-5.2852)	
Conditional variance equation				
ARCH(1)	0.10905 (12.0487)	0.09295 (11.0124)	0.09580 (10.3945)	0.10134 (11.8883)
GARCH(1)	0.89095 (98.4430)	0.90705 (107.4657)	0.90420 (98.1109)	0.89866 (105.4223)
Tests with actual t-statistics				
Ho: sum of the coefficients on the 12 lags of $\Delta(Log(P))=1$	-6.3233	-7.3360	-8.3037	
Regression econometric diagnostics				
$\overline{R}^2$	0.44999	0.48903	0.49194	0.49755
Log likelihood	3377.180	2849.711	2859.272	2850.587
Actual probability of the Ljung-Box Q-statistic for lag k on the standardized residuals	k=6: 0.573 k=12: 0.831 k=24: 0.271	k=6: 0.851 k=12: 0.973 k=24: 0.727	k=6: 0.503 k=12: 0.874 k=24: 0.767	k=6: 0.251 k=12: 0.596 k=24: 0.396
Actual probability of the Ljung-Box Q-statistic for lag k on the squares of the standardized residuals	k=6: 0.215 k=12: 0.213 k=24: 0.430	k=6: 0.525 k=12: 0.498 k=24: 0.725	k=6: 0.332 k=12: 0.300 k=24: 0.522	k=6: 0.543 k=12: 0.500 k=24: 0.659

Table 5 presents the regressions with $\Delta(Log(P))$, the continuously compounded inflation rate, as the dependent variable. Column 2 is the estimation of an ARIMA model on the inflation rate. In column 3 the estimation adds real growth to the ARIMA model. In column 4 the estimation includes two additional variables: the change in the Baa corporate bond yield and the change in the log of currency in circulation. This last estimation is for equation (4) in the text. All three regressions are carried out with an IGARCH (Integrated GARCH) model for the conditional variance.[3] The three tests that the sum of the coefficients of the 12 lags of the inflation rate is equal to zero are rejected at very low confidence levels. The three tests that the sum of the coefficients of the 12 lags of the inflation rate is equal to one are rejected also at very low confidence levels. The minimum t-statistic for the first series of tests is 43.413, and that for the second series of tests is 6.323. The regression in the third column finds a negative relation between the inflation rate and real growth, with a short run impact of -0.024, and a long run impact of -0.163.[4] Both impacts are statistically significant. The regression in the fourth column, which is about equation (4), produces coefficients that have the expected sign and the required statistical significance. As expected, the long run coefficients are higher (in absolute values) than the short run ones. A surprising answer is the high statistical significance of the corporate yield variable, and its sizeable long run coefficient (13.48), although Fama (1981) has found that the interest rate variable in his regressions of the same model is invariably statistically insignificant. However, in Table 5, the coefficient on the currency variable is rather small, with a long run effect of only 0.16.

The final column reproduces the expectations-augmented Phillips curve. The inflation rate is regressed on the expected inflation rate and on real growth. Even with such a specification the coefficient on the growth variable is still negative and statistically significant.

Finally the econometric diagnostics on higher order serial correlation and conditional heteroscedasticity are all favorable.

5 CONCLUSION

The results of this paper can be summarized as follows. There is a significant negative relation between inflation and growth in the short run, which stands even if IV (or 2SLS) estimation is undertaken. Both expected and unexpected inflation have the same significant negative relation with growth. Deflation does not bring about any additional costs or benefits. Negative supply shocks do not drive the relation, this being significant and negative in periods where there were little negative shocks, and more demand shocks. Formulating the relation as an expectations-augmented Phillips curve does not eliminate the negative relation. The proposed underlying theory to explain the negative effect is the demand for real balances. Although inflation is the only significant factor when growth is taken to be the dependent variable, all factors are statistically significant, especially the change in the long term interest rate, when the inflation rate is taken to be the dependent variable. Therefore the evidence is consistent with both money demand theory and a simple bivariate model. Further research may extend the application of the models in this paper to other developed or developing countries.

AUTHOR INFORMATION

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[3] The IGARCH model is adopted because the sum of the GARCH(1,1) coefficients is insignificantly different from one.
[4] The long run effects are found by dividing the short run coefficients by one minus the sum of the coefficients on the 12 lags of the dependent variable.

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