Does inflation reduce productivity?

Argia Sbordone and Kenneth Kuttner

What would be the long-run economic benefit of reducing the rate of inflation, or eliminating it entirely? Conversely, what would be the cost of allowing inflation to rise above its current rate? Answering these key monetary policy questions requires an assessment of inflation's real effects. The case for zero inflation rests on the presumption that the real costs of inflation are substantial, while arguments for de-emphasizing the zero-inflation goal presume the opposite.

Many economists have argued that high rates of inflation create distortions that lead to inefficient resource allocation and hence lower productivity. Feldstein (1982), for example, has contended that given the existing tax structure, inflation lowers the real return on capital, discouraging capital formation. Other often-cited efficiency losses are associated with the unproductive activities required to cope with ever-rising prices. These include the costs of changing posted or printed prices, and the "shoe-leather" costs associated with holding less cash.[1]

The empirical evidence on the inflation-productivity relationship has been inconclusive. While many studies have sought a link between average inflation and real growth rates across countries, the results are mixed and tend to be sensitive to the inclusion of additional variables as determinants of productivity growth.[2] A recent paper by Rudebusch and Wilcox (1994) documented a strong inverse relationship between inflation and productivity in the U.S. More importantly, it added a causal interpretation and policy conclusion: Reducing inflation, it argued, would increase productivity. These results and conclusion received a great deal of attention in the business press and were cited by Federal Reserve Chairman Alan Greenspan in congressional testimony in May.

Our article examines the postwar evidence on the relationship between inflation and productivity in the U.S., paying particular attention to two questions that the existing literature has not resolved. One is whether the negative correlation documented by Rudebusch and Wilcox is a long-run phenomenon or simply reflects cyclical co-movements. The second question is what assumptions are required to interpret the correlation as a causal relationship and conclude that a permanent decrease in inflation would bring about a permanent increase in productivity.

In the first section we describe the statistical properties of inflation and productivity and corroborate the negative correlation at cyclical and long-run horizons. We then take up the interpretation of this correlation. Simple "Granger causality" tests suggest a causal link between inflation and productivity when only those two variables are included in the analysis. Controlling for other factors—monetary policy, in particular—destroys that relationship, however. In a four-variable vector autoregression (VAR) model, increases in the federal funds rate cause productivity to fall, while inflation lacks any predictive power.

Argia Sbordone is an economist and Kenneth Kuttner a senior economist and assistant vice president at the Federal Reserve Bank of Chicago.

The next section takes up the long-run relationship between inflation and productivity, using a bivariate time-series model to estimate the ultimate effect on productivity of a permanent shock to inflation. An important conclusion of this analysis is that the size and sign of the estimated effect depend heavily on the identifying assumptions used to distinguish inflation shocks from productivity shocks. This result illustrates the dangers in drawing policy conclusions from bivariate correlations. In addition, robustness checks show that the strength of the long-run effects depends on the inclusion of the oil-shock episodes.

The article also discusses the economics that may underlie the strong negative cyclical relationship between inflation and productivity observed in the data. A box sketches the elements of a model that would exhibit this property. In such a model, a monetary policy rule that raises short-term interest rates in anticipation of future inflation can generate a negative correlation at cyclical frequencies. This argument relies on procyclical productivity behavior, and a lag between economic activity and changes in the rate of inflation. Immediately after a monetary contraction, therefore, inflation remains high while output contracts; meanwhile, labor hours fall less than output because of labor hoarding. The fact that labor productivity falls while inflation remains high generates the negative correlation in the data, rather than any causal link from inflation to productivity.

A look at the data

Figure 1 plots the quarterly series of inflation and productivity used in this article. Inflation is the annualized growth rate (approximated by the change in the logarithm) of the gross domestic product (GDP) deflator for the non-farm business sector. The productivity index is the output-to-labor ratio, or average labor productivity, in the non-farm business sector.[3]

Figure 2 displays the trend and cyclical components of inflation and productivity growth, obtained by passing the series through a band-pass filter that allows respectively only the low-frequency components (panel A) and the business cycle frequencies (panel B).[4] Panel A shows that inflation and productivity both exhibit a great deal of low-frequency variation. This also appears in the descriptive statistics reported in table 1, which shows that productivity was generally lower and inflation higher in the two decades following the 1973 oil shock. In addition, inflation and productivity appear to be strongly negatively related; the correlation coefficient is –0.36 in the unfiltered data and –0.47 for the cyclical components (not reported in the table).

Causality tests

The negative correlation between inflation and productivity apparent in figure 2 and documented in table 1 is quite robust—so much so that it is tempting to jump immediately to the conclusion that inflation causes productivity to fall. But since correlation does not imply causality, such a conclusion might be premature. Low productivity growth might cause inflation to increase, for example, rather than the other way around. Alternatively, the correlation might represent a common response to some third factor rather than an underlying structural relationship between inflation and productivity.

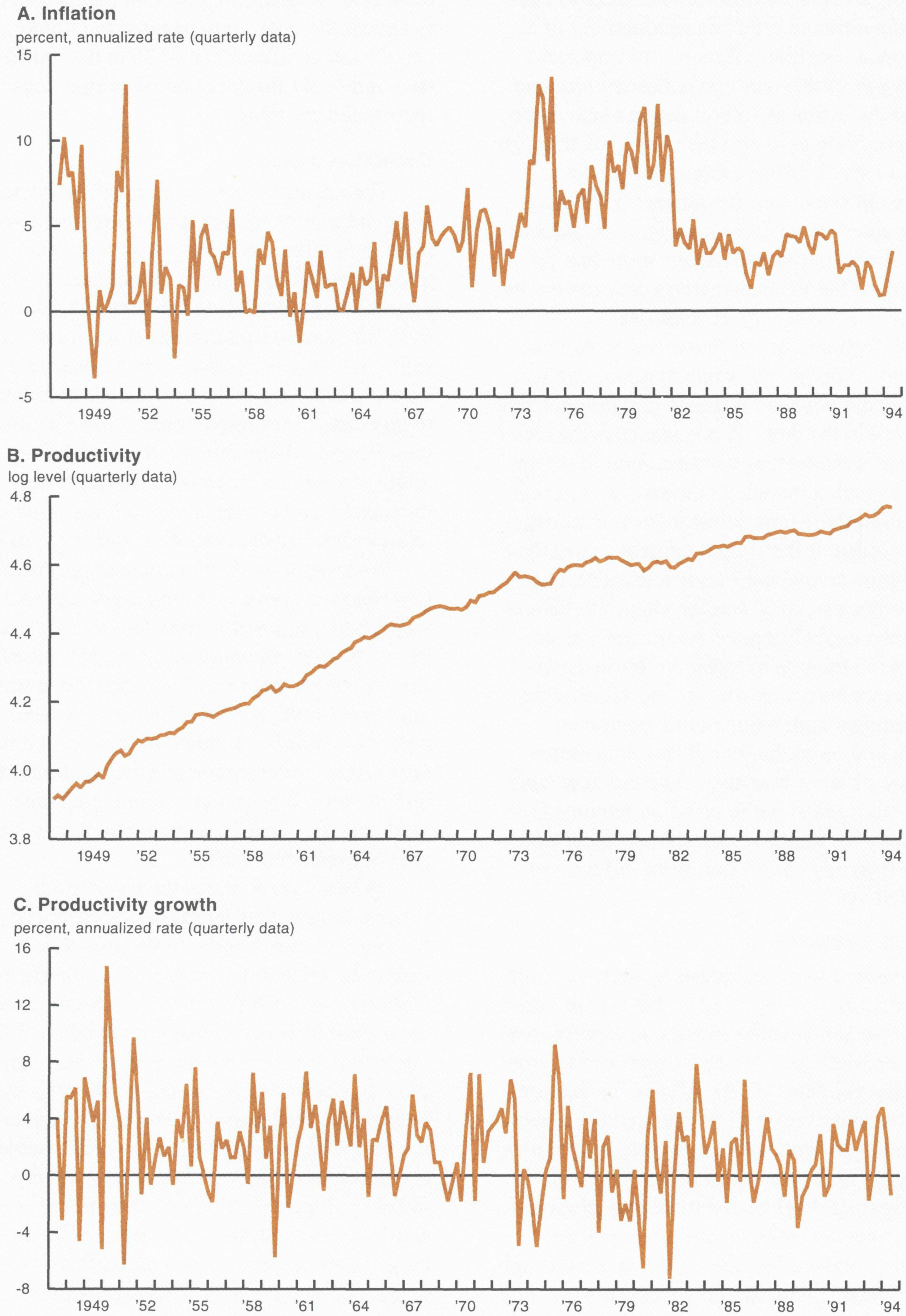
One way to go beyond the simple correlation reported above is, following Rudebusch and Wilcox, to employ tests for Granger causality. Although the name suggests that these tests can determine whether inflation is the underlying cause of productivity fluctuations, their notion of causality is much narrower. All these tests can do is determine whether current inflation is useful for *forecasting* future changes in productivity—clearly quite distinct from the idea of *logical* causality.

Table 2 corroborates the Rudebusch-Wilcox finding that inflation indeed strongly "Granger causes" productivity growth in a simple bivariate relationship. The significant F-statistic for inflation in the productivity regression indicates that inflation contains information useful for predicting future productivity growth, supporting a causal link running from inflation to productivity. The negative sum of the coefficients, reported below the F-statistic, is consistent with the negative relationship visible in figure 2. Although the effect is statistically significant, the $\bar{R}^2$ statistic indicates that lagged productivity growth and inflation together account for only 6 percent of the variance in productivity growth.

This finding, along with the insignificant F-statistic for productivity in the inflation equation, appears to support the contention that inflation reduces productivity. What it does not indicate, however, is whether the bivariate

FIGURE 1

An overview of inflation and productivity



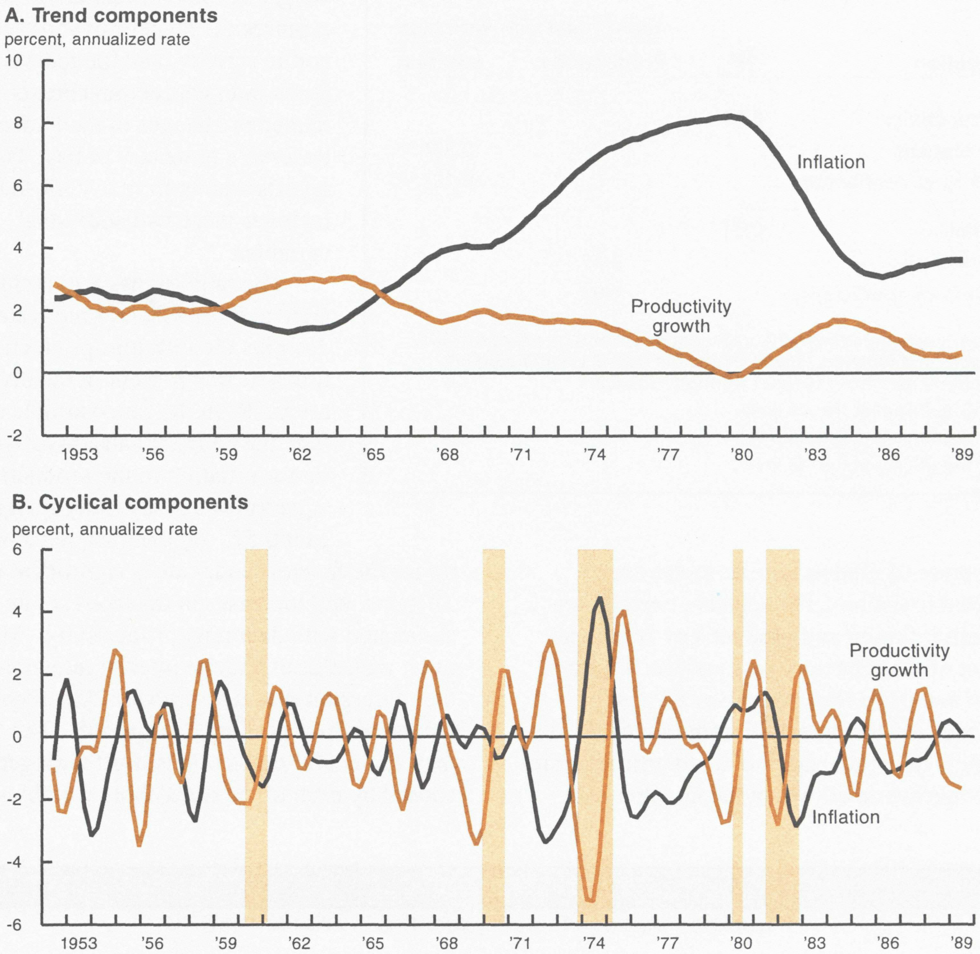
Granger causality represents a structural relationship or is merely an artifact of the short-run co-movements of inflation and productivity over the business cycle.

Sources of cyclical co-movements

A great deal of theoretical and empirical research has gone into exploring mechanisms that can produce a negative correlation

FIGURE 2

Inflation and productivity growth



Note: Vertical bands mark NBER-designated recessions.

between the movements in inflation and in productivity that occur over the business cycle. One plausible mechanism involves the Federal Reserve's reaction to anticipated inflation and the way in which businesses respond to transitory cyclical downturns.

TABLE 1

Descriptive statistics

	1947:Q1 - 1994:Q2	1947:Q1 - 1973:Q3	1973:Q4 - 1994:Q2
Inflation			
Mean	4.02	2.99	5.35
Standard deviation	3.13	2.76	3.08
Productivity growth			
Mean	1.80	2.45	0.98
Standard deviation	3.29	3.40	2.95
Correlation	–0.36	–0.27	–0.37

Suppose, for instance, that the Fed acts to tighten monetary policy in response to impending inflation, and that inflation thereafter declines more slowly than real activity. Faced with costs associated with adjusting their work force, firms will reduce employment only gradually and may retain more workers than they really need—a phenomenon known as labor hoarding. The result is a fall in output and labor productivity, coinciding with high inflation. In this scenario, which

TABLE 2

Inflation and productivity in a bivariate VAR

Equation	$\bar{R}^2$	Right-hand side variables: Productivity	Inflation
Productivity	0.06		
F-statistic		--	3.35***
Sum of coefficients			−0.28***
Inflation	0.61		
F-statistic		0.42	--
Sum of coefficients		0.04	

Note: Each equation in the VAR contains four lags of productivity growth and inflation. The VAR sample period is estimated on quarterly data from 1950:Q1 through 1994:Q2.
***Significant at the .01 level.
**Significant at the .05 level.
*Significant at the .10 level.

is a feature of models similar to the one sketched in the box, the negative correlation between inflation and productivity is only an artifact of the monetary rule and the timing of output and price responses over the cycle.

One way to control for common cyclical factors is to include additional control variables in the regression on which the Granger causality tests are based. Two obvious candidates for cyclical controls are the growth rate of real GDP, which captures the level of overall economic activity, and the federal funds rate, whose movements are related to changes in the Federal Reserve's monetary policy. Table 3 reports results from a VAR that includes these two additional variables.

The table shows that including GDP and the federal funds rate destroys the inflation-productivity link that was present in the bivariate VAR. In the four-variable system, the Granger causality *F*-statistic for inflation in the productivity equation is a statistically *in*significant 0.57. By contrast, the *F*-statistic for the federal funds rate is significant at the .01 level, and increases in the interest rate are associated with declining productivity. Moreover, with output and the interest rate included, the regression now accounts for 20 percent of the variance of productivity growth. The fact that the federal funds rate is itself Granger-caused by each of the other three variables

TABLE 3

Inflation and productivity in a four-variable VAR

Equation	$\bar{R}^2$	Right-hand side variables: Productivity	Inflation	Output	Funds rate
Productivity	0.20				
F-statistic		--	0.57	0.93	3.87***
Sum of coefficients			−0.07	−0.21	−0.26***
Inflation	0.67				
F-statistic		0.85	--	2.74**	5.23***
Sum of coefficients		0.00		0.03	0.08
Real GDP	0.29				
F-statistic		2.11*	0.07	--	4.72***
Sum of coefficients		−0.11	0.02		−0.26*
Funds rate	0.93				
F-statistic		2.37*	2.90**	6.15***	--
Sum of coefficients		−0.20***	0.07	0.16***	

Note: Each equation in the VAR contains four lags of productivity growth, inflation, real GDP growth, and the federal funds rate. The VAR sample period is estimated on quarterly data from 1950:Q1 through 1994:Q2.
***Significant at the .01 level.
**Significant at the .05 level.
*Significant at the .10 level.

suggests that monetary policy is set in large part in response to economic activity and inflation, and it is this mechanism that generates the observed correlation. Clearly, omitting variables that capture the state of the economy and the stance of monetary policy means overlooking a very important part of the picture.

These Granger causality tests can provide only circumstantial evidence on the underlying structural relationship between inflation and productivity. Nevertheless, the results suggest that the negative correlation observed in the data reflects the interaction of monetary policy and real economic activity more than a direct causal link between inflation and productivity.

Inflation and productivity in the long run

An alternative way to eliminate or at least minimize the effects of common cyclical comovements in inflation and productivity is to focus on the long-run relationship between the two series. The analysis will, therefore, build on an econometric model designed to capture long-run effects. The goal will be to determine whether inflation shocks are associated with permanent changes in labor productivity, and if so, whether this relationship is structural, in the sense that a permanent reduction in inflation would lead to a long-run increase in productivity.

As King and Watson emphasize (1992, 1994), an analysis along these lines is possible if inflation and productivity can both be characterized as integrated processes. The salient feature of such processes is that unanticipated movements or "shocks" tend to persist indefinitely as a result of a unit root in the variables' time-series representation.[5] Because the effects of shocks last indefinitely, such series never revert to an underlying mean or deterministic trend; instead, they appear to exhibit a randomly varying or stochastic trend.

Table 4 presents Augmented Dickey-Fuller (ADF) tests for unit roots in inflation and productivity. The τ_μ column reports test statistics from a regression that includes a constant term; the τ_t statistics are from a regression that includes constant and trend terms. The test statistics for inflation and productivity are only barely significant at the .05 and .10 levels, respectively indicating that shocks to inflation and productivity tend to be highly persistent. This suggests treating both series as integrated processes in order to model the long-run effects of permanent changes.

TABLE 4

Tests for unit roots

	ADF t-statistics	
	τ_μ	τ_t
Inflation (π)	−2.91	−3.13
Change in inflation ($\Delta\pi$)	−8.23	−8.20
Log productivity (z)	−2.81	−1.71
Productivity growth (Δz)	−4.56	−5.24
0.01 critical value	−3.51	−4.04
0.05 critical value	−2.89	−3.45
0.10 critical value	−2.59	−3.15

Note: The results are based on regressions containing six lags, estimated on quarterly data from 1950:Q1 through 1994:Q2.

A general econometric model describing the interaction between inflation and productivity can be constructed by allowing the change in the inflation rate, $\Delta\pi_t$, to depend on the current rate of productivity growth, Δz_t, and lags of both variables. Similarly, productivity growth may depend on current inflation and lags of both variables. Formally, the model can be represented by a pair of equations,

$$(1)\quad \Delta\pi_t = \lambda_{\pi z}\Delta z_t + \sum_{j=1}^{p}\alpha^j_{\pi\pi}\Delta\pi_{t-j} + \sum_{j=1}^{p}\alpha^j_{\pi z}\Delta z_{t-j} + \varepsilon^\pi_t$$

$$(2)\quad \Delta z_t = \lambda_{z\pi}\Delta\pi_t + \sum_{j=1}^{p}\alpha^j_{z\pi}\Delta\pi_{t-j} + \sum_{j=1}^{p}\alpha^j_{zz}\Delta z_{t-j} + \varepsilon^z_t,$$

where the ε^π_t and ε^z_t disturbance terms represent inflation and productivity shocks, respectively. An obvious interpretation of the inflation shock is to ascribe it to monetary policy; similarly, the interpretation of the productivity shock is as a random shift in the production function.[6] The "impact multipliers", $\lambda_{\pi z}$ and $\lambda_{z\pi}$, capture within-quarter feedback from productivity to inflation, and from inflation to productivity, respectively.

To evaluate the real costs of inflation, the key parameter in this model is the long-run

Labor hoarding and measured labor productivity

In this box we briefly describe how a negative correlation between inflation and productivity can be generated by firms' "labor hoarding" behavior. The model sketched here follows Sbordone (1993).

We assume that firms face costs of adjusting labor hours and therefore increase labor utilization (as opposed to hours) when they experience changes in their demand conditions. The aggregate production function,

(3) $Y_t = F(K_t, e_t H_t \Theta_t)$,

expresses output, Y, as a function of capital, K, and effective labor, which is the product of labor utilization (effort), e; labor hours H; and labor-augmenting technological change Θ. The time subscript t denotes current values of all the variables.

Taking logarithms and first differences yields

$$\Delta \ln Y_t = \left(\frac{F_K K}{Y}\right) \Delta \ln K_t + \left(\frac{F_H H}{Y}\right) (\Delta \ln H_t + \Delta \ln e_t + \Delta \ln \Theta_t),$$

where F_K and F_H denote the partial derivatives of the production function with respect to K and H. Assuming constant returns to scale, labor productivity can be written as

(4) $$\Delta z_t \equiv (\Delta y_t - \Delta h_t) = s_K (\Delta k_t - \Delta h_t) + s_H (\Delta \ln e_t) + \varepsilon_t^z,$$

where lowercase letters indicate natural logarithms and $\varepsilon_t^z = s_H (\Delta \ln \Theta_t)$.

It is easy to see from this expression that a procyclical pattern in effort can induce procyclical behavior in labor productivity. Because effort is unobservable, we can model effort variations by solving a dynamic cost-minimization problem, where the costs include a convex cost of adjusting labor hours from one period to the next. The result is that the optimal level of effort depends on how current growth of hours compares to expected future growth. Specifically,

$$\hat{e}_t = -\beta(E_t \Delta h_{t+1} - \Delta h_t),$$

where E_t represents the expectation conditional on information available at time t, $\hat{e}_t$ is the deviation of effort from its steady state value, and the parameter β is a function of the cost of adjusting hours relative to the cost of effort. In words, firms increase labor utilization when they expect future growth in hours will fall below current growth; conversely, they reduce labor utilization when they expect future growth in hours to be higher than current growth. In the latter case, in fact, firms may want to start hiring immediately because the marginal cost of increasing labor is lower once the reduction of future adjustment costs is taken into account. In this context, any variable that affects the forecast of hours may induce variations in productivity through the induced adjustment of effort.

Because effort is a stationary variable in this model, all productivity fluctuations are transitory regardless of whether the demand shock is temporary or permanent. A temporary shift in demand is met with effort changes only; a permanent shift is met with effort changes in the short run and full adjustment of hours in the long run. Any permanent changes in productivity would, therefore, have to come from changes in the capital-to-output ratio, as shown in equation 4. Two mechanisms through which inflation may affect the capital accumulation process are discussed in the body of this article.

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response of productivity to a permanent change in inflation. This response, denoted $\gamma_{z\pi}$, can be expressed in terms of the parameters of the structural model:

$$\gamma_{z\pi} = \frac{\lambda_{z\pi} + \Sigma_{j=1}^{p} \alpha_{z\pi}^{j}}{1 - \Sigma_{j=1}^{p} \alpha_{zz}^{j}} .$$

Later, we will test the hypothesis that $\gamma_{z\pi} = 0$, that is, that a permanent change in inflation has no long-run effect on productivity. An analogous hypothesis involves the reverse of this effect—that inflation exhibits no long-run response to a change in labor productivity, which is denoted $\gamma_{\pi z}$, and defined analogously to $\gamma_{z\pi}$.

Unfortunately, the econometric model in equations 1 and 2 is not identified. This means that recovering the structural parameters from a reduced-form VAR of productivity growth and inflation on lags of the two variables is impossible, given the simultaneous feedback from inflation to productivity, and vice versa. Further restrictions or identifying assumptions are necessary.[7]

Although the model is written only in terms of real variables, it can generate productivity fluctuations as a response to changes in inflation, or any monetary variable, to the extent that these variables help to predict the behavior of future growth in hours. In this case, in fact, they will generate fluctuations in effort.

Why might inflation forecast growth in hours? Suppose agents know that when inflation rises, monetary policy tightens in anticipation of further inflation. In this case, a positive shock to inflation signals that current growth in hours is going to be lower than what is expected in the next period, and therefore implies a decrease in effort. This generates a decline in output that is larger than the decline in labor hours, causing productivity to fall. In this scenario, the timing of the monetary rule and the "hoarding" of labor produce a negative correlation between inflation and productivity without any fundamental causal link.

To go from the productivity equation 4 to equation 2 of the text, one can solve for effort in terms of current and past inflation variations, and project the capital-to-hours ratio on past productivity growth and inflation, to obtain

$$\Delta z_t = \lambda_{z\pi}\Delta\pi_t + \sum_{j=1}^{p} \alpha_{z\pi}^{j}\Delta\pi_{t-j} + \sum_{j=1}^{p} \alpha_{zz}^{j}\Delta z_{t-j} + \varepsilon_t^z ,$$

where the α and λ coefficients are functions of the adjustment cost parameter and the parameters of the projections of hours and the capital-to-hours ratio. This equation allows for transitory effects of inflation on productivity through variation in labor effort, as well as permanent effects through changes in the capital-to-hours ratio.

Identification in this model requires two restrictions. The first is relatively innocuous: that the inflation and productivity shocks ε^π and ε^z are uncorrelated with one another. The interpretation of this restriction is that although inflation and productivity are related through the λ and α parameters, their random components come from distinct sources such as monetary policy and technology. Even with this assumption, recovering the four structural parameters, $\gamma_{\pi z}$, $\gamma_{z\pi}$, $\lambda_{\pi z}$, and $\lambda_{z\pi}$ from the reduced-form estimates requires one additional restriction.

Lacking clear implications from economic theory about the sign and size of these parameters, we assume a value for one of them, and then estimate the remaining three as a function of the first. This allows us to examine the way in which the conclusions about the long-run relationship between inflation and productivity depend on the form of the assumptions used to identify the model. This approach has the additional advantage of nesting other standard empirical specifications within a common framework. The standard recursive or Choleski decompositions of the reduced-form VAR, for example, correspond to zero restrictions on the impact multipliers: $\lambda_{z\pi} = 0$ for inflation ordered first, and $\lambda_{\pi z} = 0$ for productivity first. Setting the long-run multipliers, $\gamma_{\pi z}$ and $\gamma_{z\pi}$, equal to zero is another way to identify the model.[8] In each case, the system of equations can be estimated by instrumental variables, where the appropriate instruments depend on the identifying assumptions. Details on this estimation procedure appear in Watson (1994).

Table 5 displays the estimates of the λ and γ parameters in equations 1 and 2 under the alternative zero restrictions discussed above. Figure 3 plots the corresponding time paths of the productivity response to an inflation shock of sufficient magnitude to increase the annualized inflation rate by 1 percent in the long run, and the 90 percent confidence bound for the long-run response. The results use the inflation and productivity measures described above and are based on regressions with six lags of each variable running from 1950:Q1 through 1994:Q2.

One important result is that both sets of short-run restrictions, shown in the first two rows of table 5, yield statistically significant *negative* estimates of the long-run response of productivity to inflation, $\gamma_{z\pi}$. Under the assumption that inflation has no within-quarter effect on productivity ($\lambda_{z\pi} = 0$), its long-run effect is a significant -1.86, which suggests that a shock that reduces the inflation rate by 1 percent in the long run will increase productivity by just under 0.5 percent. The estimated long-run effect of inflation on productivity is even larger if we assume instead that productivity has no within-quarter effect on inflation ($\lambda_{\pi z} = 0$). In this case, a permanent 1 percent reduction in inflation would increase productivity by roughly 0.8 percent. The marginally

TABLE 5

Parameter estimates under alternative zero restrictions

Restrictions	Estimated parameter $\lambda_{z\pi}$	$\lambda_{\pi z}$	$\gamma_{\pi z}$	$\gamma_{z\pi}$
$\lambda_{z\pi} = 0$	0	–0.19 (0.05)	0.02 (0.05)	–1.86 (0.66)
$\lambda_{\pi z} = 0$	–0.42 (0.11)	0	0.10 (0.05)	–3.31 (1.01)
$\gamma_{\pi z} = 0$	0.16 (0.35)	–0.26 (0.13)	0	–1.39 (1.18)
$\gamma_{z\pi} = 0$	0.70 (0.25)	–0.46 (0.10)	–0.06 (0.05)	0

Note: Standard errors are in parentheses. The results are based on regressions containing six lags, estimated on quarterly data from 1950:Q1 through 1994:Q2.

significant positive estimate of $\gamma_{\pi z}$ generated by this restriction is puzzling from an economic point of view, however, and casts doubt on the plausibility of the restriction.

Panels A and B of figure 4 show that this result generalizes to a range of λs other than zero. It turns out that any value of $\lambda_{\pi z}$ in the –0.4 to +0.8 range is consistent with a statistically significant negative response of productivity to inflation, as is any value of $\lambda_{z\pi}$ less than 0.2. However, as panel B shows, large positive values of $\lambda_{z\pi}$ are consistent with *positive* values of $\gamma_{z\pi}$.

It is widely recognized that short-run restrictions such as these are often inappropriate for identifying the economic phenomena of interest. Although it is clear from figure 4 that the negative long-run relationship between inflation and productivity holds up for a wide range of λs, the economic interpretation of these impact multipliers is not clear. Take the case of $\lambda_{z\pi}$, for example, which represents the contemporaneous effect of an inflation shock on productivity. While economic theory suggests that inflation may reduce productivity in the long run (by inhibiting capital formation, for example), it is generally silent on the short-run effects. Particularly in light of the cyclical interactions between inflation, monetary policy, output, and productivity highlighted earlier, there is no reason to believe the short-run effect is zero—or any other specific number, for that matter.

This argues for using an alternative restriction to identify inflation's long-run effect on productivity in order to remain agnostic on the contemporaneous relationship between the two variables. One plausible restriction that allows us to do this is to set $\gamma_{\pi z}$ equal to zero. The restriction makes economic sense; it is equivalent to assuming that permanent changes in productivity have no long-run effects on the rate of inflation (although they may lead to changes in the price level). The estimates of $\gamma_{z\pi}$, and the two within-quarter λ coefficients, appear in the third line of table 5.

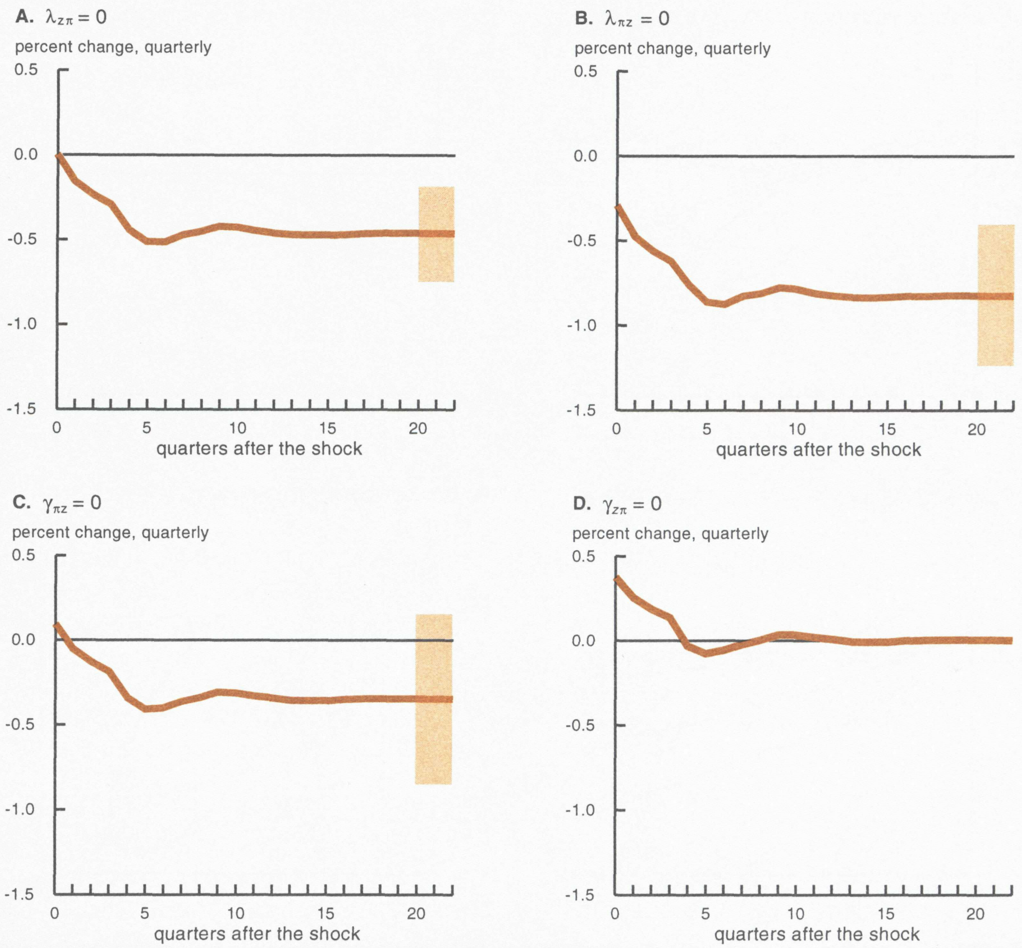
Interestingly, although the point estimate of $\gamma_{z\pi}$ is negative under this identification scheme, it is smaller (in absolute value) than it was under the short-run restrictions, and not statistically significantly different from zero. As shown in panel C of figure 3, the estimated response of productivity to inflation is initially positive, becomes negative after one quarter, but is never statistically significant. Panel C of figure 4 shows that to obtain a statistically significant negative value of $\gamma_{z\pi}$ under this long-run identification restriction requires setting the long-run effect of productivity on inflation ($\gamma_{\pi z}$) to a positive number greater than 0.06; we have no reason to believe that this is a plausible range. One factor contributing to this result is the fact that the standard errors associated with the parameter estimates are much larger under the long-run restrictions than under the restrictions on λ, reflecting the imprecision with which the long-run multipliers are estimated.

The fourth possible identification scheme imposes a restriction on $\gamma_{z\pi}$. Setting it to zero suggests that productivity is unaffected by inflation in the long run. Even though this restriction merely *assumes* an answer to the central question raised in the article, the estimates of the other parameters yield additional insights into the results; these estimates appear in the fourth line of table 5.

Although the model obtained by setting $\gamma_{z\pi}$ is, like the other models, exactly identified and hence unable to test statistically, the parameter estimates it generates are sufficiently unusual to suggest that the restriction is inappropriate. The strangest is the estimated $\lambda_{z\pi}$. Here, the statistically significant positive estimate says that inflation shocks increase productivity

FIGURE 3

Effects of inflation shocks on productivity under alternative parameter restrictions



Note: Shaded areas indicate 90 percent confidence bounds.

contemporaneously, and, as shown in panel D of figure 3, the response is uniformly positive over the first year. While this does not represent a formal rejection of the model, such a large, positive short-run response is hard to rationalize theoretically.[9]

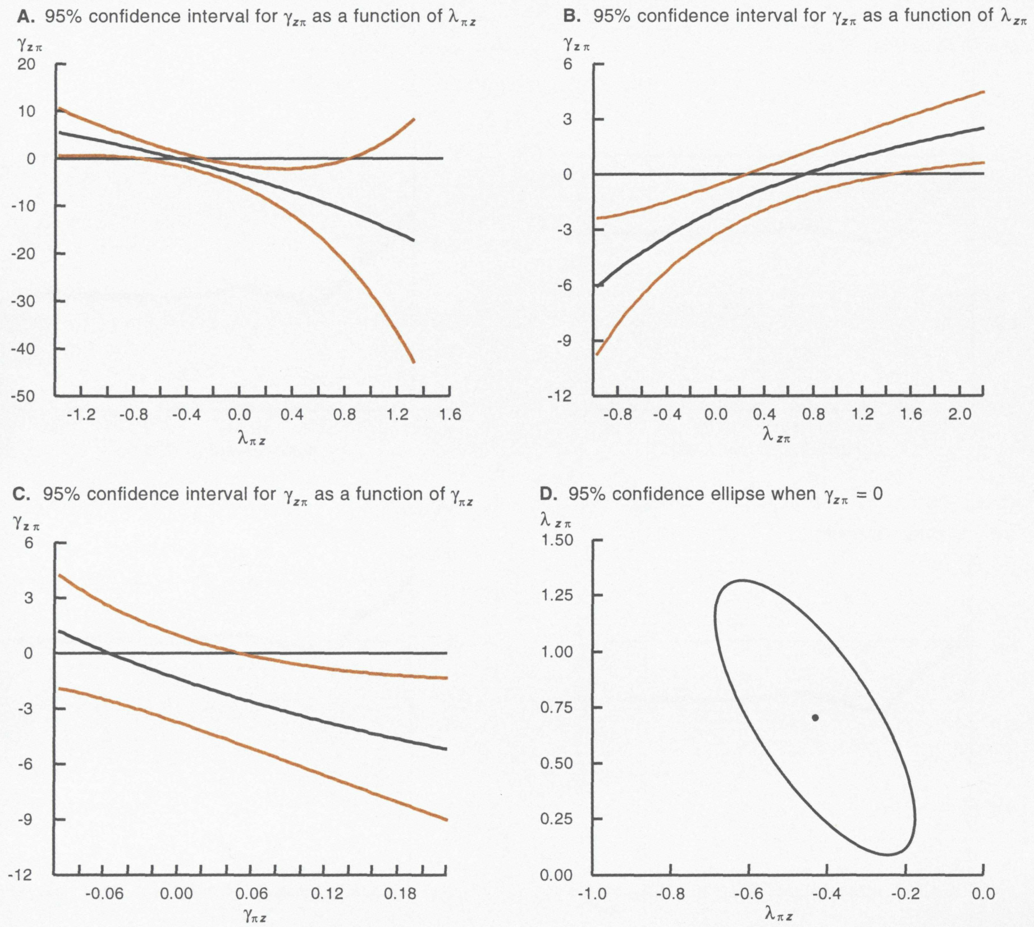
Suppose, then, we set a non-zero value for $\gamma_{z\pi}$. Would the other parameters' estimates seem more reasonable? The rationale for this exercise is that we have some theoretical justification for the hypothesis that the long-run effect can go either way. Tobin (1965) argued that inflation leads investors to reallocate their portfolios away from money and into capital, which reduces the real rate of interest, increases investment, and raises labor productivity. Taking an opposing view, Feldstein (1982) contended that given the U.S. tax structure, an increase in inflation depresses capital accumulation, leading to a long-run decline in labor productivity.

Suppose we believe Tobin's argument.[10] Our search over possible parameter values for $\gamma_{z\pi}$ indicates that for values greater than 1.5, we still get positive and significant estimates of $\lambda_{z\pi}$. In that case, however, we obtain significant negative values of both the long-run and short-run multipliers of productivity to inflation.[11] Using negative values for $\gamma_{z\pi}$, in keeping with Feldstein's arguments, does not change the results obtained under the restriction $\gamma_{z\pi} = 0$. Choosing a value of $\gamma_{z\pi}$ less than -0.5, however, makes all other parameter estimates insignificant.

The results reported in table 6 show that the estimated long-run effect of inflation on productivity, $\gamma_{z\pi}$, is rather sensitive to the changes in sample and lag length. Each of the

FIGURE 4

Long-run effect of inflation on productivity



three right-hand columns corresponds to imposing one of the three zero restrictions discussed above. The first row gives the results for the six-lag model estimated over the entire sample from 1950:Q1 through 1994:Q2, which merely replicates the results already reported in table 5.

The second and third rows of table 6 demonstrate the results' sensitivity to subsample. Specifically, under the $\gamma_{\pi z} = 0$ restriction, the point estimate of $\gamma_{z\pi}$ is positive (albeit statistically insignificant) in the subsample from 1950:Q1 through 1973:Q3, and significantly negative only in the subsample from 1973:Q4 through 1994:Q2. Similarly, the estimates of $\gamma_{z\pi}$ obtained under both sets of short-run restrictions are significant at only the .10 level in the early subsample. These results are consistent with the view that the high-inflation oil shock years are largely responsible for the strength of the statistical association between high inflation and sluggish productivity growth.

The results are also sensitive to the chosen lag length. When four lags are used, the size of the estimated long-run effect of inflation on productivity is less than half of what it was with six lags. Moreover, with eight lags, the estimate of $\gamma_{z\pi}$ is insignificant at the .05 level under both the $\lambda_{\pi z} = 0$ and the $\gamma_{\pi z} = 0$ restrictions.

Overall, these results suggest that higher rates of inflation are associated with lower productivity in the long run. The strength of this conclusion depends, however, on the identifying assumption used to differentiate inflation shocks from productivity shocks. Under the plausible assumption that productivity does not affect (or reduce) inflation in the long run, the evidence connecting inflation to lower productivity is very weak. Furthermore, the effect appears to be strongest in the years following the 1973 oil

TABLE 6

Estimates of $\gamma_{z\pi}$ for alternative samples and lag lengths

Sample	Lags	Restriction imposed $\lambda_{\pi z} = 0$	$\lambda_{z\pi} = 0$	$\gamma_{\pi z} = 0$
1950:Q1 - 1994:Q2	6	−3.31 (1.01)	−1.86 (0.66)	−1.39 (1.77)
1950:Q1 - 1973:Q3	6	−3.32 (1.94)	−2.04 (1.14)	0.88 (1.36)
1973:Q4 - 1994:Q2	6	−2.58 (0.75)	−1.34 (0.55)	−1.47 (0.90)
1950:Q1 - 1994:Q2	4	−1.57 (0.58)	−0.73 (0.40)	−0.01 (0.63)
1950:Q1 - 1994:Q2	8	−4.11 (1.27)	−2.18 (0.82)	−1.76 (1.58)

Note: Standard errors are in parentheses.

shock, and its magnitude and statistical significance depend heavily on the number of lags included in the regressions.

Conclusions

It is very easy to detect a negative correlation between inflation and productivity in the data. It is much more difficult to conclude that higher inflation causes productivity to fall. The results presented above argue for caution in interpreting the observed correlation as a sign of an underlying structural relationship.

The results from both econometric techniques used in this article demonstrate the fragility of the empirical link between inflation and productivity. In Granger causality tests, including the federal funds rate eliminates inflation's effect on productivity, which suggests that a major part of the correlation is cyclical in nature. Estimates of inflation's long-run effect on productivity in a dynamic structural model are highly sensitive to the identification scheme used to distinguish inflation from productivity shocks.

These findings illustrate a more general point about the pitfalls of drawing policy conclusions from reduced-form statistical relationships. Without a solid theoretical framework, it is impossible to tell whether the negative time-series correlation implies a policy trade-off or merely reflects the way in which output, inflation, and productivity jointly depend on the state of the economy and the actions of monetary policy.

NOTES

[1]Fischer (1993) surveys these costs and evaluates them for a cross section of countries.

[2]See Levine and Renelt (1992).

[3]These are the same series analyzed by Rudebusch and Wilcox (1994). Alternative measures of productivity and price level yield similar results.

[4]The low-pass filter that extracts the trend component is designed to pass components with periodicity longer than 8 years, while the filter to obtain the cyclical components passes the components with periodicity between 6 quarters and 8 years. Both filters are approximated with a moving average from $t - j$ to $t + j$, where $j = 20$ quarters and the weights are normalized to sum to 1.

[5]For an introduction to the use of integrated processes in econometric modeling, see Stock and Watson (1988).

[6]The box shows how to derive equation 2 from a production function.

[7]Technically, the VAR describes only the response of inflation and productivity to *innovations* in each of the two variables, namely to $\upsilon_t^{\pi} = \Delta\pi_t - E_{t-1}\Delta\pi_t$ and $\upsilon_t^{z} = \Delta z_t - E_{t-1}\Delta z_t$. The identifying assumptions allow us to map these innovations into the structural disturbances ε_t^{π} and ε_t^{z}.

[8]Blanchard and Quah (1989) used this type of restriction to identify aggregate supply and demand shocks.

[9]We should note, however, that the confidence ellipse for the two impact multipliers (shown in panel D of figure 4) suggests a high probability of observing values of $\lambda_{z\pi}$ very close to zero, together with a significantly negative impact of productivity on inflation.

[10]The results of King-Watson (1994), which reject the Fischerian neutrality hypothesis, are consistent with this Tobin effect.

[11]For example, setting $\gamma_{z\pi} = 1.6$ yields $\lambda_{z\pi} = 1.56$ (standard error = 0.47), $\lambda_{\pi z} = -0.7$ (standard error = 0.14), and $\gamma_{\pi z} = -0.11$ (standard error = 0.05).

REFERENCES

Blanchard, Olivier J., and Danny Quah, "The dynamic effects of aggregate demand and supply disturbances," *American Economic Review*, Vol. 79, 1989, pp. 655-673.

Feldstein, Martin, "Inflation, tax rules, and investment: Some econometric evidence," *Econometrica*, Vol. 50, 1982, pp. 825-862.

Fischer, Stanley, "The role of macroeconomic factors in growth," *Journal of Monetary Economics*, Vol. 32, 1993, pp. 485-512.

King, Robert G., and Mark W. Watson, "Testing long-run neutrality," Federal Reserve Bank of Chicago, working paper, No. 92-18, 1992.

______________, "The postwar U.S. Phillips curve: A revisionist econometric history," *Carnegie-Rochester Conference Series on Public Policy*, 1994 forthcoming.

Levine, Ross, and David Renelt, "A sensitivity analysis of cross-country growth regressions," *American Economic Review*, Vol. 82, No. 4, 1992, pp. 942-963.

Rudebusch, Glenn D., and David W. Wilcox, "Productivity and inflation: Evidence and interpretations," Board of Governors of the Federal Reserve System, manuscript, 1994.

Sbordone, Argia M., "Cyclical productivity in a model of labor hoarding," Federal Reserve Bank of Chicago, working paper, No. 93-20, 1993.

Stock, James H., and Mark W. Watson, "Variable trends in economic time series," *Journal of Economic Perspectives*, Vol. 2, 1988, pp. 147-174.

Tobin, James, "Money and economic growth," *Econometrica*, Vol. 33, 1965, pp. 671-684.

Watson, Mark W., "Vector autoregressions and cointegration," *Handbook of Econometrics*, Vol. 4, 1994.