ABSTRACT

This paper investigates whether it is the level of inflation, changes in the inflation rate or unanticipated inflation which influence the variability of sectoral output growth rates, using monthly U.S. industrial data from 1957 to 1997. We experiment with a range of specifications - our main finding is that there is no systematic relationship between inflation and sectoral growth. The effective exchange rate and the real oil price do help to explain some of the dispersion in output growth rates.

Keywords: Inflation, sectoral growth variability

JEL Classification Number: E31, E52

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1 Introduction

What is it that matters about inflation? It is clear that many people care about inflation, but is it the level of inflation, changes in the level of inflation, or unanticipated inflation that produces the presumed welfare costs catalogued in the literature?

The welfare costs of inflation have long been debated in macroeconomics and most of the recent debate has focused on whether there are appreciable benefits to going from moderate rates of inflation to “price level stability” (see, for example, Akerlof, Dickens and Perry, 1996). In this context, the welfare costs of inflation due to either the tax on real money balances or the distortionary impact of inflation on the tax system are of less importance than in high inflation regimes (and could potentially be mitigated by indexation). The recent literature has therefore emphasized the idea that inflation induces excessive relative price variability, and thereby prevents the price system from efficiently allocating resources. This may, many would argue, have significant consequences for welfare - hence the focus of this paper is on whether it is the level, changes in the level or the unanticipated nature of inflation that interferes with the efficient allocation of resources across sectors.

Unfortunately, despite the common assertion in macroeconomics textbooks that inflation has distortionary effects on the price system,\(^1\) not much is known about such costs of inflation.\(^2\) Most econometric studies on the relationship between the level of inflation and the variability in

\(^1\)For example, “inflation induces variability in relative prices [and] leads to microeconomic inefficiencies” (Mankiw and Scarth, 1995, p.175), and “inflation, and the price dispersion that accompanies it, make the price system less informative” (Hall, Taylor and Rudin, 1995, p.548).

\(^2\)Black, Coletti and Monnier (1997) provide a useful survey of the costs of inflation literature.
relative price changes find a positive correlation, and some have taken this as evidence for the welfare costs of inflation. Driffill, Mizon and Ulph (1990), however, argue that in cross-country studies these correlations were largely driven by the oil price shocks, or the inclusion of hyperinflation countries. In addition, recently several authors have examined the link between consumer price index (CPI) inflation and relative price variability using data from U.S. cities with the conclusion that the effect of inflation on relative price variability is small and damps out quickly (Parsley, 1996).³

³As well, this relationship cannot be entirely explained by monetary factors - casting doubt on the view that policies that do not aim at price stability are responsible for the implied distortions and inefficiencies (Debelle and Lamont, 1997).

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the cross-sectional variance of sectoral output growth rates, and test our model using monthly U.S. industrial output data from 1957 to 1997.

Specifically, we analyze the link between cross-sectional output growth variability and the level of inflation, the change in inflation and unanticipated inflation. We use a range of specifications, which are very similar to the ones used in the inflation-relative price dispersion literature, and examine different time periods and inflation regimes. Our main finding is that although it is not impossible to find a positive and significant correlation between output growth variability and some aspect of inflation, this result is rather rare and is extremely sensitive to model specification, time period chosen and the inflation series used in the analysis. As well, small changes in specification can lead to the somewhat surprising (but statistically significant) finding that the level of inflation is negatively related to sectoral output growth dispersion. The empirical specifications that link cross-sectional output growth variability to the level of inflation, therefore seem to fail Leamer’s (1985) extreme bounds specification test. In contrast, the real exchange rate and oil prices have robust, significant impacts on the variability in growth rates.

The paper is organized as follows. Section 2 presents the econometric model employed in the study. Section 3 discusses some of the issues related to the relationship between inflation and variability in quantities. Section 4 discusses the results. Section 5 concludes.
2 A Model

In order to fix ideas, we sketch a model based on Lucas’s signal extraction model of the impact of inflation on cross-sectional output growth variability.\(^5\)

If \(P_i\) and \(Q_i\) denote the relative price which firms receive and the output level they choose in industry \(i\) in period \(t\), respectively, then a common expectation in economics is that the change in output level depends, inter alia, on changing relative prices as

\[
\Delta Q_{it} = F(\Delta P_{it}),
\]

where \(\Delta\) is the first difference operator.

Assume that quantity supplied in industry \(i\) in period \(t\) consists of trend output \(q_{it}^n\), and cyclical output \(q_{it}^c\):

\[
q_{it} = q_{it}^n + q_{it}^c.
\]

All lower case variables are expressed in logs. The cyclical component of output can be further decomposed into the lagged value of the cyclical component of output \(q_{it}^c\) (persistence effects), plus a relative price effect, which is proportional to the deviation from the mean price level \(\bar{p}_t\) of the relative price \(p_{it}\), which firms in industry \(i\) receive (see Lucas, 1973). The output equation then becomes:

\[\text{See İscan and Osberg (1998) for more details. Appendix A also considers a search model due to Tommasi (1994). The signal-extraction and search models both predict a statistically significant relationship between the level of inflation and dispersion in sectoral growth rates, but we emphasize here the signal extraction perspective.}\]

\(^5\)
\[ q_{it} = q_{it}^n + \rho q_{it-1}^c + \theta(p_{it} - \bar{p}_i), \]  

where \(|\rho| < 1\) and \(\theta\) are constant parameters.

Taking the first difference of equation (1) gives the output growth as determined by changing relative prices, as well as trend output growth:

\[ \Delta q_{it} = \Delta q_{it}^n + \rho \Delta q_{it-1}^c + \theta(\Delta p_{it} - \Delta \bar{p}_i). \]  

Taking the cross-sectional variance over sectors at both \(t - 1\) and \(t\) in equation (2) and assuming that \(\text{var}_t(\Delta q^c)\) is a constant, \(\nu^c\), give:

\[ \text{var}_t(\Delta q) = a + \rho^2 \text{var}_{t-1}(\Delta q) + \theta^2 \text{var}_t(\Delta p) + \rho \theta \text{cov}(\Delta q_{it-1}, \Delta p_{jt}), \]  

where \(a = \nu^c(1-\rho^2) > 0\). The covariance term, at any given time \(t\), is the cross-sectional covariance between sectoral output growth at \(t - 1\) and sectoral relative price changes at \(t\).

Following the empirical literature on relative price variability (see, e.g., Fischer, 1981), we first express \(\text{var}_t(\Delta p)\) as a linear function of the level of inflation and lagged values of inflation. This essentially captures the intuition that rising inflation makes it difficult to distinguish “signal” from “noise” in relative prices. We also examine whether relative price variability can be more appropriately linked to changes in the level of inflation or unanticipated inflation.

Other exogenous changes in the economic environment (such as supply shocks) may also influence the variance in output growth rates, and to isolate the role of inflation we need to control explicitly for such influences. The demand schedules faced by some sectors (e.g. the
automobile industry, consumer durables) are particularly sensitive to interest rate movements, and to foreign competition, so we control for the level of and changes in the real interest rate \((r_t)\), and the real exchange rate \((s_t)\). Since shocks to world oil prices might be expected to have significant and unequal supply side effects on energy intensive sectors, they are also controlled in the analysis \((OIL_t)\).\(^6\)

These considerations lead us to specify the dispersion of the change in relative sectoral prices as a linear function of the possible influences of the levels of inflation, interest and exchange rates, and oil prices:

\[
\text{var}_t \Delta p = b_0 + b_1(L)\pi_t + b_2 r_t + b_3 s_t + b_4 OIL_t + u_t,
\]

where \(b = [b_0, b_1, b_2, b_3, b_4]’\) is a vector of parameters, \(b_(L)\) is a polynomial lag operator which allows for the persistence in inflation and \(u\) is a random error term. If we denote \(\text{var}_t (\Delta q) = \sigma_{qt}^2\), and \(\rho \theta \text{cov}(\Delta q_{t-1}, \Delta p_t) + u_t = e_t\), and substitute equation (4) into (2), we obtain

\[
\sigma_{qt}^2 = c_0 + \rho^2 \sigma_{qt-1}^2 + c_1(L)\pi_t + c_2 r_t + c_3 s_t + c_4 OIL_t + e_t
\]

\(\text{(5)}\)

\(^6\)On a country by country basis, the interest rate \textit{differential} and the exchange rate are linked via the interest parity conditions. However, deviations from interest parity can occur even on a bilateral basis (see, e.g., Dornbusch, 1989). This paper uses the \textit{level of} (or changes in the level, see below) domestic real interest rate, and the trade weighted \textit{index} of exchange rates, which are not in general linked by the interest parity condition. We take these as predetermined, since we know of no theoretical basis on which the inter-industry variability in growth rates could be said to causally influence exchange rates or the interest rate. Oil price shocks are included as an independent variable because they have been found to impact relative price variability (Bomberger and Mahinen 1993), and inflation (Ball and Mankiw 1995).
where \( c_0 = a + \theta^2b; \quad c_1(L) = \theta^2b_1(L); \quad c_2 = \theta^2b_2; \quad c_3 = \theta^2b_3; \quad \text{and} \quad c_4 = \theta^2b_4. \) Note that the expected signs of the coefficient parameters on lagged and current values of inflation are positive.\(^7\)

The measure of sectoral output growth variability used in this study is specified as:

\[
\sigma_{q_{it}}^2 = \frac{1}{N - 1} \sum_{i=1}^{N} (\Delta q_{it} - \overline{\Delta q_{it}})^2,
\]

where \( N \) is the number of sectors in the sample, and \( \overline{\Delta q_{it}} = (1/N)\sum_{i=1}^{N} \Delta q_{it} \) is the unweighted average of output growth rates. (To check the robustness of our results, we also consider weighted output growth rates.)

Our model therefore conditions cross-sectional output growth variability on its own lag, the real interest rate, exchange rate, and oil price effects, as well as on inflation. The issue we want to address is the alternative specifications that capture different aspects of inflation (i.e., level, change or unanticipated).

3 Motivation and Issues

Since several versions of the costs of inflation literature relate distortions directly to the level of inflation, the model of section 2 focused first on the relationship between the level of actual inflation and the cross-sectional variability of output growth. Consistent with the view that the level of inflation adds noise into the price system and therefore causes undesired and excessive

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\(^7\)This prediction of the signal extraction model, however, is not necessarily a general result. In particular, as discussed in Appendix A, some search models, such as Tommasi (1994), may actually predict a negative relationship between the level of inflation and sectoral output growth variability. Intuitively, this may occur when inflation reduces the informational content of prices to consumers, inhibits the price system from “weeding-out” inefficient, high-cost producers, reallocates output from low cost producers to high-cost producers and thereby reduces dispersion in cross-sectional growth rates.
changes in output and in the allocation of resources, in our empirical specifications we first link the level of (past and current) inflation to variability in sectoral growth rates, and call this Model 1.

Linking actual inflation directly to dispersion in sectoral output growth may seem a somewhat naive interpretation of the costs of inflation literature. It has long been argued (e.g., by Friedman, 1977) that it is the unanticipated component of inflation that induces distortions and inefficiencies, rather than the level of inflation per se. However, modelling the impact of unanticipated inflation clearly requires some model of anticipated inflation, and there is no single consensus model of inflationary expectations. If inflationary expectations are adaptive, a possible proxy for unanticipated inflation is the change in the level of inflation. Model 2 therefore relates the variability of sectoral output growth rates to the change in inflation.

The difficulties of forecasting inflation using econometric techniques have been known for some time (Cecchetti, 1995), and the low correlations obtained across alternative measures are fairly well documented in the literature (Batchelor and Dua, 1996). In this paper, we cannot resolve this debate. However, to check the robustness of our results, Model 3 decomposes inflation into trend and cyclical components using a structural vector autoregressive (SVAR) methodology constructed by Claus (1997). This method attempts to distinguish between temporary and persistent shocks to the level of inflation using long-run identifying restrictions. To the extent that temporary shocks are related to distortions in relative prices, this
decomposition also allows us to examine the differential impacts of trend and cyclical inflation on cross-sectional variance of sectoral growth.\footnote{We used the two sets of estimates on CPI, all items and CPI, all items excluding food and energy obtained from an equation system which includes the relevant CPI, capacity utilization rate, producer price index, and import price of goods, see Claus (1997) for details. Following Quah and Vahey (1995), her SVAR identifies the structural shocks to the CPI inflation process by assuming that only a shock to inflation rate has a long-run impact on inflation. As well, her monthly series are constructed based on year-over-year percentage changes in the log CPI.}

Finally, since the currently relevant policy choice is between low inflation and “price level stability” we distinguish between “low” and “high” inflation regimes in our sample. It is possible that the link between the level of inflation and output variability may not be linear. If annual inflation rates below 3\% are perceived as “price level stability,” and if such stability indeed has an impact on output growth, then periods of very low inflation may be systematically different. Also, if output adjustment is costly and lumpy, it may take large changes in perceived relative prices to induce firms to change real output. If so, only “high” inflation periods would contribute to variability in output growth rates. We therefore control for these regime effects in Model 4.

4 Specifications and Empirical Results

4.1 Specifications

Model 1 relates cross-sectional variance of sectoral growth to its lagged value, the real interest rate, exchange rate and oil price, as well as to the level of inflation. We also consider two alternative specifications in which levels and changes in these prices are separately controlled for, whereby the \textit{levels} specification is:

\begin{align*}
\sigma_{qt}^2 &= c + \rho_1 \sigma_{qt-1}^2 + \alpha_1(L) \pi_t + \beta r_t + \eta_1 \delta_t + \mu_1 OIL_t + \varepsilon_{1t} \\
&= c + \rho_1 \sigma_{qt-1}^2 + \alpha_1(L) \pi_t + g_1(X_t) + \varepsilon_{1t} \tag{7}
\end{align*}
and, the changes specification is:

\[
\sigma^2_{qt} = c^* + \rho_1 \sigma^2_{q(t-1)} + \alpha_1'(L) \pi_t + \beta_1' \Delta \pi_t + \eta_1' \Delta \pi_t + \mu_1' \Delta OIL_t + \varepsilon_{1t}^*
\]

\[
= c^* + \rho_1' \sigma^2_{q(t-1)} + \alpha_1'(L) \pi_t + \eta_1' \Delta \pi_t + \mu_1' \Delta OIL_t + \varepsilon_{1t}^*,
\]

(8)

where \( \alpha_t(L) \) and \( \alpha_t'(L) \) are polynomial lag operators in inflation with lag length \( L \).

In our second specification (Model 2), we nest the above model so that the cross-sectional variance of sectoral growth rates depend on the level and the changes in the inflation rate:

\[
\sigma^2_{qt} = c_2 + \rho_2' \sigma^2_{q(t-1)} + \alpha_1 \pi_t + \alpha_2 \Delta \pi_t + g_2' (\Delta X_t) + \varepsilon_{2t}^*,
\]

(9)

We also estimate a version of equation (9), in which the real interest rate, exchange rate and oil price variables are in levels, using the changes in these variables, i.e., \( g_2' (\Delta X_t) \).

If what matters for producers is the distinction between the underlying trend of inflation and its cyclical components, this decomposition can be obtained from a SVAR model. Model 3 therefore relates the trend of inflation and deviations from trend to the variance of sectoral growth rates:

\[
\sigma^2_{qt} = c_3 + \rho_3' \sigma^2_{q(t-1)} + \alpha^n \pi^n_t + \alpha^c \pi^c_t + g_3' (X_t) + \varepsilon_{3t}^*,
\]

(10)

where \( \pi^n \) and \( \pi^c \) denote trend and cyclical components of inflation, respectively.

Our final specification, Model 4, relates output growth dispersion to low inflation regimes based on the premise that low rates of inflation may be observationally equivalent to “price level
stability”. To this end, we define a dummy variable (Dummy) which takes value one when the level of inflation is below 3 percent at an annual rate, and zero otherwise. Therefore we have:

$$\sigma^2_{qt} = c_4 + \rho_4 \sigma^2_{q_t-1} + \alpha_4(L)\pi_t + g_4(X_t) + \gamma Dummy + \varepsilon_{4t}$$

(11)

We also estimate equation (5) using $g_4(\Delta X_t)$ instead of $g_4(X_t)$.

4.2 Data

To measure the variability in output growth rates across sectors, we use monthly industrial production indices obtained from the Board of Governors of the Federal Reserve Board covering the period from 1957:1 to 1997:2. The sample size increases slightly from 94 in 1957 to 104 in 1997 and our sectors are fairly detailed (e.g., sugar and confectionary, structural clay products). Sectoral value added data are available for 1982, 1987 and 1992 with which we can weight each industry. In the empirical analysis, we used 1987 shares as mid-sample observations, because 1982 shares were heavily influenced by oil price effects.

Our data sources for the producer price index (PPI), the interest rate, the effective exchange rate and the oil price are described in Appendix B. The inflation rate is measured by month-over-month change in the log of the PPI. Since monthly data are somewhat noisy, we also experiment with alternative methods of “smoothing” the monthly output growth and the inflation rate by using their 3-month moving averages or by considering quarter-over-quarter changes in log output and log PPI. For the real interest rate, effective exchange rate and real oil price

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9In our empirical analysis we also considered 6 and 12 percent annual inflation rates.

10We use high frequency real output and inflation data because the impact of inflation on relative price dispersion is likely to be short-lived. Parsley (1996, pp. 334) shows that, in his data, “the half-life of deviations to the dispersion of inflation rates is less than a quarter.”
variables, we use both the monthly data and 3-month moving averages. For consistency in the
analysis, when the dependent variables and inflation rate are smoothed, we use the 3-month
moving averages of the real interest rate, effective exchange rate, and real oil prices. Conversely,
when the cross-sectional variance of the monthly output growth rates are regressed on the
monthly inflation rate, monthly data on the remaining independent variables are used.\textsuperscript{11}

4.3 Empirical Results

Figure 1 shows the PPI inflation and cross-sectional variance of output growth rates over
the period 1957:2 - 1997:2. No obvious visual pattern immediately emerges from this figure.

However, the issue is whether inflation accentuates the variability in sectoral output
growth, holding other factors constant. To illustrate our findings, Tables 1 and 2 report the
estimation results of Models 1-4 with alternative specifications. Columns [1] to [4] of Table 1,
based on Model 1 specifications, indicate that in all cases the level of current inflation is not
statistically significant. Only the second lag of inflation is significant in the quarter-over-quarter
specification, suggesting that it may take more than a quarter for inflation to induce “excessive”
dispersion in output growth rates.\textsuperscript{12} Focusing on columns [3] - [4] of Table 1, it can be observed
that when output growth dispersion and PPI inflation are measured by quarter-over-quarter
changes in the log output and log PPI, respectively, and other variables are measured by their 3-
month moving averages, the model explains almost 30 percent of the cross-sectional output

\textsuperscript{11}We have also experimented with alternative smoothed measures of cross-sectional
variance and inflation, such as variance of 6-month-over-6-month output growth and inflation
rate, and 6-month moving average of real interest and exchange rates, and real oil price.

\textsuperscript{12}However, the positive coefficient on two quarters lagged inflation must be read in the
context of the larger negative (insignificant) coefficients on current and one quarter lagged
inflation.
growth variability as indicated by adjusted $R^2$. Compared to columns [1] and [2], which use monthly data, smoothing the data produces a significant improvement in the explanatory power of the model.

Model 2 relates output growth dispersion to the level and the change in inflation rate. Columns 5 to 8 indicate that none of the coefficient estimates of the change in the level of inflation are significant. In several specifications current inflation is statistically significant, but its sign is negative. Coefficient estimates of the remaining variables are fairly stable across Model 1 and 2 specifications. In particular, the level of the effective exchange rate is significant (see columns [1], [3], [5] and [7]). To the extent that monetary policy has an impact on the short-run output growth dispersion, its effect appears to be transmitted through exchange rate markets, rather than through changes in the average price level.  

In Table 2, columns [1] to [4] distinguish between the trend and cyclical components of CPI inflation to gauge the impact of unanticipated inflation on output growth dispersion (Model 3). Although the estimated partial correlations between output growth variability and trend inflation are negative, and output variability and deviations from trend are positive, none of the coefficient estimates are statistically significant at levels below 10 percent. Using monthly or “smoothed” data does not affect the conclusion. However, the effective exchange rate is positive and significant in all the reported specifications of Model 3.

Columns [5]-[8] of Table 2 control for low inflation episodes by introducing a dummy variable for periods of less than 3% inflation (Model 4). Since specifications that use moving

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13Our regressions only relate inflation, real interest rate, and effective exchange rate to output growth dispersion. Several transmission mechanisms may be in place, and we do not attempt to uncover them in this paper.
averages of price variables (i.e., interest rate, effective exchange rate, and oil price) and quarter-over-quarter changes in output and PPI inflation rate exhibit a better fit, only those regression runs are reported here. We have also estimated the model both in its levels and change specifications for the entire sample from 1957 to 1997, and for the subsample 1975:6 - 1997:2, separately.\textsuperscript{14} Current inflation is not significant in any of the specifications. Consistent with our previous estimates, only the second lag of inflation is significant when the entire sample period observations are used. The dummy variable which controls for “price stability” periods has a negative and significant coefficient estimate, in columns [5] and [6]. However, the magnitude and the significance of the coefficient on this variable depends on the sample period, and tends to be lower in the subsample from 1975:3 to 1997:2. As well, in Table 2, columns [3], [4] and [7] suggest that the real oil price may have had a significant positive impact on the variance of sectoral output growth in the 1975-1997 subsample, which is consistent with the relative price dispersion literature (e.g., Bomberger and Makinen, 1993).

Tables 1 and 2 are illustrative of the relationship between inflation and sectoral output growth variability (i.e., the lack thereof) but there are many measurement choices to be made in assessing this issue. Seven baseline specifications were discussed in section 4.1 [equations (7)-(11) and the changes specification for equations (9) and (11)]. For each of these specifications we have three possible ways of defining inflation (i.e., current monthly inflation, three month moving average or quarter-over-quarter). To check the subsample sensitivity of the results, we also estimated all the models for the post oil shock period, 1975-1997. As well, we estimated our

\textsuperscript{14}We use 1975 as a post-oil shock cutoff point because from August 1971 to April 1974 price controls were implemented by the Nixon administration.
Models 1, 2, and 4 using inflation data based on PPI, excluding energy prices, for the shorter period these data were available (1975-1997). We have also estimated a subset of our specifications after weighting each sector’s output by its share in total industrial value added in 1987 and recalculating the cross-sectional variance of real output growth. Since the hypothesis that agents behave differently in a “low” inflation environment is potentially sensitive to how “low” is defined, in Model 4 we experimented with setting different levels of inflation as the criterion. As a further model specification check, we looked for a possible impact of the business cycle. Specifically, we augmented Models 1-4 by incorporating the mean and the variance of capacity utilization rates as additional controls, and estimating them both unweighted and weighted by the relative size of industrial sectors.\(^{15}\)

This battery of specifications yields a “large” number of regression equations. We summarize these regression runs in Table 3, which reports the number of times an explanatory variable is included in estimated models, and the number of times its coefficient estimate is statistically different from zero at the 10 percent level. The coefficient estimates of inflation, as measured by its levels or the changes in its level or its deviation from trend inflation, are frequently statistically insignificant. In a relatively small number of specifications, the estimated coefficient on the level of current inflation is negative and significant, but in a roughly similar number of specifications, the current and/or past level of inflation has a positive coefficient estimate. As discussed in Section 2 and Appendix A, different models of inflation may have different predictions about the sign of the coefficient on the inflation variable. Our regression

\(^{15}\)Capacity utilization series, however, are only available for 25 industries and, in most cases, from 1967 onwards.
results, however, do not indicate that there is any systematic relationship between output growth variability and inflation. Although there is some evidence that levels of inflation under 3 percent are associated with lower variability in cross-sectional growth rates, the evidence is not compelling. The complete regression results are available on request from the authors.

On the other hand, in a large number of specifications the coefficient estimates on the effective exchange rate and real oil price are positive and significant. These findings are consistent with Canadian data (see, İşcan and Osberg, 1998) and suggest that foreign exchange markets may provide an important link between monetary policy and real output. An appreciation of the U.S. dollar with respect to its 22 major trading partner countries has differential impacts on industrial sectors and is associated with an increase in variability in sectoral growth.

5. Conclusion

The level of inflation may be positively correlated with the variability in relative price changes, but if relative price dispersion induced by inflation is short-lived (Parsley, 1996), producers can insulate themselves from excessive short-term price fluctuations by inventory adjustments or by using contracts for future delivery. As well, if output adjustment is costly, firms may choose to respond only to “large” changes in relative prices (particularly if these changes are expected to be of short duration). In the last forty years, inflation in the U.S. has been low to moderate by international standards. Therefore, the levels of inflation observed in our

\[16\] All of the negative and significant coefficients on the real oil price come from the weighted regression runs which include mean and variance of capacity utilization rates.

\[17\] See Eichenbaum and Evans (1995) on the evidence of a link between monetary policy and exchange rates in the U.S.
data set may not matter for production decisions. Put differently, the impact of inflation on output decisions may be small relative to firms’ adjustment technology,\(^\text{18}\) over the historically observed range of U.S. inflation. We would emphasize that without additional empirical evidence our results cannot necessarily be extended outside that range.

This paper has reported estimates of the relationship between inflation and cross-sectional output growth variability using monthly U.S. industrial output data from 1957 to 1997. We would agree that the welfare costs of inflation might be quite significant if inflation produces excessive “noise” in relative prices and thereby causes excessive output variability. However, the question is whether it is the level of inflation, the change in the level of inflation, or the trend and cyclical components of inflation that matters for output decisions - or none of the above.

Our conclusion is that there is no systematic relationship in the U.S. data between inflation and output growth variability. Our results do indicate that high oil prices in the 1970s and early 1980s help explain some of the variability observed during those periods. As well, the effective exchange rate is significantly correlated with the cross-sectional variance of output growth, suggesting that when the effective exchange rate is above its “long-term” average (exchange rate appreciation) the variance of sectoral output growth rates tends to be higher. An important aspect of the monetary transmission mechanism may therefore be the impact (through the exchange rate) of monetary policy “shocks” on the second moments of real output growth, as

\(^{18}\)In particular, fixed costs of adjustment may be an important consideration. For instance, Bresnahan and Ramey (1994), and Caballero et al. (1997), using manufacturing plant data, find that firms’ adjustments are mostly large or zero, and this is consistent with non-convex adjustment cost technology. See also Abowd and Kramar (1997) who find a significant fixed component to firms desired level of employment.
well as the average level of output growth - an issue that has been highly neglected in the recent literature on alternative monetary transmission mechanisms.

We recognize that the debate on inflation is partly about distribution - the fact that unanticipated changes in inflation arbitrarily redistribute income between net debtors and creditors as well as between wages and profits. However, it seems to us that identifying the welfare costs of inflation at the aggregate level remains a challenge for future research. Our results suggest that sectoral output growth variability and inflation are essentially uncorrelated, and any benefits of going from moderate levels of inflation to zero inflation should be sought somewhere else.
Appendix A: Growth Dispersion in a Search Model

Tommasi (1994) suggests that inflation reduces the informational content of relative prices across the producers of similar goods. He assumes that inflation induces an idiosyncratic shock to producers’ costs, appealing to the empirical regularity that high inflation rates are associated with high relative price dispersion (pp. 1386-87).\(^{19}\)

The output level of a sector, \(Q\), is given by;

\[
Q(\theta^{it}) = 1 + \frac{E\theta^{it} - \theta^{it}}{1 - \rho(\pi)\beta},
\]

(A.1)

where \(\theta^{it}\) is the unit cost of sector \(i\) at time \(t\); \(\rho\) is a decreasing function of the level of inflation, \(\pi^{it}\); \(0 \leq \beta \leq 1\) is a discount factor; and \(E\theta^{it}\) is the unconditional expectation of \(\theta^{it}\). In Tommassi’s model with probability \(\rho(\pi^{it})\) the unit cost is equal to previous period unit cost (\(\theta^{it} = \theta^{it-1}\)), and with probability \((1 - \rho(\pi^{it}))\) \(\theta^{it}\) is drawn from a known distribution (with mean, say, \(\bar{\theta}\)). Note, therefore, that \(\text{var}(\theta^{it} | \theta^{it-1}) = (1 - \rho) \rho (\theta^{it-1} - \bar{\theta})^2\), and this variance is decreasing in \(\rho\) (increasing in \(\pi^{it}\)) whenever \(\rho > .5\).\(^{20}\)

Taking the logarithm of equation (A.1) and differencing it over time, for small deviations, we can approximate the growth rate of output by

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\(^{19}\)There is, as far as we know, no study, that has established an empirical relationship between relative total costs across producers and the level of inflation. (See, however, Menéndez (1997) who finds a positive association between past inflation and wage dispersion in Argentina.) Therefore, although the empirical relationship Tommasi appeals to exists, it may not be the relevant one for his analysis. Also, in his model, it turns out that under certain circumstances inflation may lead to lower relative price dispersion (p. 1393).

\(^{20}\)We have specialized in a “nontruncation case” and simplified the exposition in Tommasi by assuming \(C = .5\); see Tommasi for details.
\[
\Delta q_{it} = \frac{E\theta_{it} - \theta_{it}}{1 - \rho(\pi_i)\beta} - \frac{E\theta_{it-1} - \theta_{it-1}}{1 - \rho(\pi_{it-1})}. \tag{A.2}
\]

where \(q_{it} = \log Q_{it}\). From (A.2) the cross-sectional variance over sectors at both time \(t-1\) and \(t\) is obtained by

\[
\text{var}_t(\Delta q) = \frac{\text{var}_t(\theta)}{[1 - \rho(\pi_i)\beta]^2} + \frac{\text{var}_{t-1}(\theta)}{[1 - \rho(\pi_{it-1})\beta]^2},
\]

where we used the fact that \(\text{cov}(E\theta_{it} - \theta_{it}, E\theta_{it-1} - \theta_{it-1}) = 0\). Therefore,

\[
\frac{\partial}{\partial \rho(\pi_i)} \text{var}_t(\Delta q) = 2\beta \frac{\text{var}_t(\theta)}{[1 - \rho(\pi)\beta]^3} > 0,
\]

so that an increase in the level of current inflation (a decrease in \(\rho\)) reduces the cross-sectional dispersion of output growth. Hence, a negative correlation between inflation and sectoral output growth dispersion, as in Table 1, columns [5] and [8], can find an explanation.
Appendix B: Data Sources
The industrial production indices, and value added data for 1982, 1987, and 1992 were obtained from the WWW site of the Board of Governors of the Federal Reserve Board (FRB) (www.bog.frb.fed.us/releases/g17/download.htm, and www.bog.frb.fed.us/releases/g17/g17tab6.txt, respectively). The capacity utilization indices were obtained from two FRB addresses: For the period from 1967 to 1985 (www.bog.frb.fed.us/releases/G17/iphist/utlhist.sa), and from 1986 to 1997 (www.bog.frb.fed.us/releases/G17/ipdisk/utl.sa). The nominal interest rate data were obtained from the Federal Reserve Bank of St. Louis WWW site, and it is the “3-month T-Bill rate (secondary market); average of daily closing bid prices” (www.stls.frb.org/fred/data/irates/tb3ms). The two producer price indices, namely finished goods, and finished goods less energy were both obtained from the Federal Reserve Bank of St. Louis (www.stls.frb.org/fred/data/ppi.html). The oil price data consist of monthly average prices of the Domestic West Texas Intermediate Grade of crude oil. These data were also obtained from the Federal Reserve Bank of St. Louis (www.stls.frb.org/fred/data/business/oilprice). The ex-post real interest rate and real oil price are calculated by deflating the nominal figures by the appropriate PPI. The effective exchange rate index is the ratio (expressed in base year 1990=100) of an index of the period average exchange rate of the U.S. dollar to a weighted geometric average of exchange rates of 22 industrial country currencies. The weights are based on the trade in manufactured goods among these countries. The data were obtained from the IMF, *International Financial Statistics* CD-ROM (index number 111.NEUZF...).
References


Table 3: Box Totals of Significance of Explanatory Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Positive*</th>
<th>Insignificant</th>
<th>Negative*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation, ( t )</td>
<td>9</td>
<td>152</td>
<td>27</td>
<td>188</td>
</tr>
<tr>
<td>Inflation, ( t-1 )</td>
<td>8</td>
<td>115</td>
<td>3</td>
<td>126</td>
</tr>
<tr>
<td>Inflation, ( t-2 )</td>
<td>23</td>
<td>103</td>
<td>0</td>
<td>126</td>
</tr>
<tr>
<td>( \Delta ) inflation, ( t )</td>
<td>0</td>
<td>57</td>
<td>5</td>
<td>62</td>
</tr>
<tr>
<td>Trend Inflation, ( t )</td>
<td>0</td>
<td>26</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>Deviations From Trend Inflation, ( t )</td>
<td>2</td>
<td>25</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Lagged Variance of Sectoral Growth</td>
<td>198</td>
<td>13</td>
<td>0</td>
<td>211</td>
</tr>
<tr>
<td>Inflation Dummy (=1 ( \leq ) 12%)</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Inflation Dummy (=1 ( \leq ) 6%)</td>
<td>6</td>
<td>9</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Inflation Dummy (=1 ( \leq ) 3%)</td>
<td>0</td>
<td>28</td>
<td>16</td>
<td>44</td>
</tr>
<tr>
<td>Mean Capacity Utilization</td>
<td>0</td>
<td>29</td>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td>Variance Capacity Utilization</td>
<td>9</td>
<td>23</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Real Interest Rate</td>
<td>2</td>
<td>110</td>
<td>14</td>
<td>126</td>
</tr>
<tr>
<td>( \Delta ) Real Interest Rate</td>
<td>0</td>
<td>74</td>
<td>15</td>
<td>89</td>
</tr>
<tr>
<td>Effect. Exch. Rate</td>
<td>50</td>
<td>77</td>
<td>1</td>
<td>126</td>
</tr>
<tr>
<td>( \Delta ) Effect. Exch. Rate</td>
<td>0</td>
<td>89</td>
<td>0</td>
<td>89</td>
</tr>
<tr>
<td>Real Oil Price</td>
<td>59</td>
<td>62</td>
<td>5</td>
<td>126</td>
</tr>
<tr>
<td>( \Delta ) Real Oil Price</td>
<td>6</td>
<td>79</td>
<td>4</td>
<td>89</td>
</tr>
</tbody>
</table>

Note: * = Coefficient estimate on the variable is statistically significantly different from zero at the 10 percent level.

This table reports the statistical significance of the coefficient estimates from 215 regression runs which are summarized below.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variables</th>
<th>No. of Regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance of month-over-month output growth</td>
<td>Model 1 : [Levels (monthly, with and without lagged dependent variable) + change (monthly) = 3] * [Samples = 4]</td>
<td>12</td>
</tr>
<tr>
<td>3-, 6-, 12-month moving average of the variance of month-over-month output growth</td>
<td>Model 1: [Levels (3-, 6-, and 12-month moving average) = 3] * [Samples = 4]</td>
<td>12</td>
</tr>
<tr>
<td>Variance of 3-, 6-month moving average of month-over-month output growth</td>
<td>Model 1: [Levels + change = 2] * [3-, and 6-month moving average = 2] * [Samples = 4]</td>
<td>16</td>
</tr>
<tr>
<td>Variance of quarter-over-quarter or 6-month-over-6-month output growth</td>
<td>Model 1: [Levels + change = 2] * [3-, and 6-month moving average = 2] * [Samples = 4]</td>
<td>16</td>
</tr>
</tbody>
</table>
(Table 3: continued)

Variance of quarter-over-quarter or 6-month-over-6-month output growth

Model 1: \([\text{Levels} + \text{change} = 2] \ast [3-, \text{and } 6\text{-month moving average of interest and exchange rates, oil price, and quarter-over-quarter and } 6\text{-month-over-6-month inflation} = 2] \ast \text{[Samples} = 4]\]

Variance of monthly, quarter-over-quarter or 6-month-over-6-month output growth

Model 2: \([\text{Levels (monthly)} = 1] \ast \text{[Samples} = 4]+ [\text{Levels} + \text{change} = 2] \ast [3-, \text{and } 6\text{-month moving average} = 2] \ast \text{[Samples} = 4]\]

Variance of monthly, quarter-over-quarter or 6-month-over-6-month output growth

Model 3: \([\text{Levels (monthly)} = 1] \ast \text{[Samples} = 3]+ (\text{Levels} + \text{change} = 2) \ast [3-, \text{and } 6\text{-month moving average of real interest and exchange rates, oil price, and year-over-year inflation} = 2] \ast \text{[Samples} = 3]\]

Variance of quarter-over-quarter output growth

Model 4: \((\text{Levels} + \text{change} = 2) \ast [3\text{-month moving average of real interest and exchange rates, oil price, and quarter-over-quarter inflation rate, dummy (12%) = 1}] \ast \text{[Samples} = 3]+ (\text{Levels} + \text{change} = 2) \ast [3\text{-month moving average of real interest and exchange rates, oil price, level of and change in quarter-over-quarter inflation, and dummy (12%) = 1}] \ast \text{[Samples} = 3]\]

Variance of 6-month-over-6-month output growth

Model 4: \((\text{Levels} + \text{change} = 2) \ast [6\text{-month moving average of real interest and exchange rates, oil price, and quarter-over-quarter inflation rate, dummy (6%) = 1}] \ast \text{[Samples} = 4]+ (\text{Levels} + \text{change} = 2) \ast [6\text{-month moving average of real interest and exchange rates, oil price, level of and change in quarter-over-quarter inflation, and dummy (6%) = 1}] \ast \text{[Samples} = 4]\]

Variance of quarter-over-quarter or 6-month-over-6-month output growth

Model 4: \((\text{Levels} + \text{change} = 2) \ast [3-, \text{and } 6\text{-month moving average of real interest and exchange rates, oil price, and quarter-over-quarter inflation rate, dummy (13%) = 2}] \ast \text{[Samples} = 4]+ (\text{Levels} + \text{change} = 2) \ast [3\text{-and } 6\text{-month moving average of real interest and exchange rates, oil price, level of and change in quarter-over-quarter inflation, and dummy (3%) = 2}] \ast \text{[Samples} = 4]\]

Variance of month-over-month or quarter-over-quarter weighted output growth

Tables 1 and 2 replicated

Variance of month-over-month or quarter-over-quarter (weighted and unweighted) output growth

[Tables 1 and 2 replicated with mean and variance of industry capacity utilization added = 16] \ast \text{[weighted and unweighted} = 2]\n
Samples for Models 1, 2, and 4 are: (1) 1957-1997; (2) 1957-1977; (3) 1975-1997; and (4) 1975-1997 with PPI (finished goods excluding energy). Samples for Model 3 are (1) 1970-1997 with CP, all items (2) 1970-1997 with CPI (all items excluding food and energy); and (3) 1975-1997 with CPI (all items excluding food and energy) used for calculating real interest rate and oil price.
Table 1: Estimates of the Determinants of Sectoral Output Growth Variability: Model 1 (Inflation Level) and Model 2 (Inflation Change)
Dependent variable: Cross-sectional variance of output growth, $\sigma^2_q$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1 - Inflation Level</th>
<th>Model 2 - Inflation Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Month-over-Month Levels</td>
<td>Quarter-over-Quarter Levels</td>
</tr>
<tr>
<td></td>
<td>Change</td>
<td>Change</td>
</tr>
<tr>
<td>Inflation_1</td>
<td>0.1264 (0.271)</td>
<td>-0.7163 (0.519)</td>
</tr>
<tr>
<td>Inflation_1,1</td>
<td>-0.2060 (0.148)</td>
<td>-0.4914 (0.387)</td>
</tr>
<tr>
<td>Inflation_1,2</td>
<td>-0.2701 (0.234)</td>
<td>0.5978* (0.292)</td>
</tr>
<tr>
<td>Δ Inflation_1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lagged Variance of Sectoral Growth, $\sigma^2_{q,t-1}$</td>
<td>0.1640 (0.102)</td>
<td>0.5239* (0.202)</td>
</tr>
<tr>
<td>Real Interest Rate^a</td>
<td>-0.0128 (0.021)</td>
<td>-</td>
</tr>
<tr>
<td>ΔReal Interest Rate^a</td>
<td>-</td>
<td>0.0397 (0.058)</td>
</tr>
<tr>
<td>Effect. Exch. Rate^a</td>
<td>0.0049* (0.001)</td>
<td>0.0091* (0.004)</td>
</tr>
<tr>
<td>ΔEffect. Exch. Rate^a</td>
<td>-</td>
<td>0.0092 (0.011)</td>
</tr>
<tr>
<td>Real Oil Price^a</td>
<td>0.0020 (0.005)</td>
<td>0.0205 (0.017)</td>
</tr>
<tr>
<td>ΔReal Oil Price^a</td>
<td>-</td>
<td>0.0038 (0.019)</td>
</tr>
<tr>
<td>Constant^a</td>
<td>-0.2269** (0.126)</td>
<td>-0.5131* (0.112)</td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.040 (0.037)</td>
<td>0.289 (0.289)</td>
</tr>
<tr>
<td>SEE</td>
<td>0.0135 (0.0135)</td>
<td>0.0240 (0.0240)</td>
</tr>
<tr>
<td>Durbin h-statistic</td>
<td>0.674 (0.602)</td>
<td>2.355 (2.249)</td>
</tr>
</tbody>
</table>

(Note: continued on next page)
Note: Variables are defined as follows. Columns [1], [2], [5], [6]: Variance of month-over-month change in log output, month-over-month change in log PPI, and the levels of monthly (levels [1], [5]) or month-over-month changes in (change [2], [6]) real interest rate, effective exchange rate, and real oil price. Columns [3], [4], [7], [8]: Variance of quarter-over-quarter change in log output, quarter-over-quarter change in log PPI, and 3-month moving averages (levels [3], [7]) or changes in the 3-month moving averages (change [4], [8]) of real interest rate, effective exchange rate, and real oil price.

All regressions are estimated by ordinary least squares. Heteroskedasticity consistent standard errors are reported in parentheses.

* To reduce leading zeros, we multiply the coefficient estimate and the standard error of the variable by 100.

* Coefficient estimate is significant at the 5% level. ** Coefficient estimate is significant at the 10% level.
Table 2: Estimates of the Determinants of Sectoral Output Growth Variability: Model 3 (Unanticipated) and Model 4 (Low Inflation Regime).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 3: Trend + Unanticipated Inflation: Levels</th>
<th>Model 4: Low Inflation Regime Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monthly, Monthly, Monthly, Monthly, Levels, Change, Levels, Change</td>
<td></td>
</tr>
<tr>
<td>Inflation (_t)</td>
<td>-0.0659</td>
<td>-0.1548</td>
</tr>
<tr>
<td></td>
<td>(0.082)</td>
<td>(0.124)</td>
</tr>
<tr>
<td>Inflation (_{t-1})</td>
<td>-0.1484*</td>
<td>-0.1638*</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.082)</td>
</tr>
<tr>
<td>Trend Inflation (_t)</td>
<td>-0.1274</td>
<td>-0.0787</td>
</tr>
<tr>
<td>Deviations From Trend</td>
<td>0.0500</td>
<td>0.1227</td>
</tr>
<tr>
<td>Inflation (_t)</td>
<td>-0.0004</td>
<td>-0.0040</td>
</tr>
<tr>
<td>Lagged Variance of Sectoral Growth, (\sigma_{g,t-1}^2)</td>
<td>0.3318*</td>
<td>0.3810*</td>
</tr>
<tr>
<td></td>
<td>(0.080)</td>
<td>(0.090)</td>
</tr>
<tr>
<td>Real Interest Rate(^\ast)</td>
<td>-0.0004</td>
<td>-0.0040</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>ΔReal Interest Rate(^\ast)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect. Exch. Rate(^\ast)</td>
<td>0.0023*</td>
<td>0.0042*</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>ΔEffect. Exch. Rate(^\ast)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Oil Price(^\ast)</td>
<td>0.0016</td>
<td>0.0056</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>ΔReal Oil Price(^\ast)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation Dummy(^\ast) (=1 if inflation ≤3%)</td>
<td>-0.1511*</td>
<td>-0.3508*</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
<td>(0.111)</td>
</tr>
<tr>
<td>Adjusted R(^2)</td>
<td>0.150</td>
<td>0.227</td>
</tr>
<tr>
<td>SEE</td>
<td>0.0022</td>
<td>0.0037</td>
</tr>
<tr>
<td>Durbin h-statistic</td>
<td>-3.724</td>
<td>-5.049</td>
</tr>
</tbody>
</table>

Note: Variables are defined as follows. Columns [1], [3]: Variance of month-over-month change in log output, month-over-month change in log CPI (all items [1] or all items excluding food and energy [3]), and the level of monthly real interest rate, effective exchange rate, and real oil price. Columns [2], [4]: Variance of

(Note: continued on next page)
quarter-over-quarter change in log output, quarter-over-quarter change in log CPI (all items [2] or all items excluding food and energy [4]), and the 3-month moving averages of real interest rate, effective exchange rate, and real oil price. Columns [5]-[8]: Variance of quarter-over-quarter change in log output, quarter-over-quarter change in log PPI (all items [1]-[2] or all items excluding energy [3]-[4]) and levels of (levels [5], [7]) or changes in (change [6], [8]) 3-month moving averages of real interest rate, effective exchange rate, and real oil price.
All regressions are estimated by ordinary least squares. Heteroskedasticity consistent standard errors are reported in parentheses.
* To reduce leading zeros, we multiply the coefficient estimate and the standard error of the variable by 100.
\[ b \] The real interest rate and real oil price are computed using producer price index, excluding food and energy.
\[ c \] Quarter-over-quarter.
* Coefficient estimate is significant at the 5% level. ** Coefficient estimate is significant at the 10% level.