# INFLATION HISTORY AND THE SACRIFICE RATIO: EPISODE-SPECIFIC EVIDENCE

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This paper examines whether episode-specific analysis can show a negative relationship between inflation and the slope of the Phillips curve that has been found in cross-country analysis. While the relationship between inflation and the Phillips curve slope is widely accepted from cross-country analysis, it has remained unproven in previous episode-specific studies. By defining inflation history as a weighted average of past inflation, this study finds a negative effect of inflation history on the sacrifice ratio, which is what is expected from the cross-country analysis. The negative relationship does not disappear even after including other conventional determinants of the sacrifice ratio.

# I. INTRODUCTION

Monetary authorities often face the task of controlling the rate of inflation. A typical example is the disinflation policy of the early 1980s in the United States. Reducing inflation, however, usually has some cost. The magnitude of that cost is often summarized by the sacrifice ratio, the percentage of a year's real GDP that must be forgone to reduce inflation by 1 percentage point. Policy makers would like to know how high the cost of a disinflation will be when they commence reducing inflation.

Economists have suggested a wide range of determinants of the sacrifice ratio.[1] In this study, we focus on the initial level of inflation and propose a new measure (inflation history measured using a geometric lag) that better captures the inflation environment at the start of a disinflation. This inflation history variable allows us to reconcile the contradictory evidence from episode-specific studies and cross-country studies.

Ball, Mankiw and Romer (1988) examine the effect of the average rate of inflation on the short-run tradeoff between output and inflation in a cross-country study. They show that higher average inflation increases the frequency of price adjustment, and therefore, makes the Phillips curve steeper. Low inflation countries will have a relatively flat Phillips curve and a large sacrifice ratio, while high inflation countries will have a steep Phillips curve and a small sacrifice ratio.[2] This relationship appears to breakdown when examining the episode-specific studies, which have found an insignificant relationship between average (initial) inflation and slope of the Phillips curve.[3]

The purpose of this paper is to reconcile Ball's (1994) episode-specific results with Ball et al.'s (1988) cross-country results. Ball et al.'s finding implies that the Phillips curve faced by policy makers depends on the average rate of inflation and that the slope of the Phillips curve changes when the average rate of inflation changes. However, the fact that the effect of inflation on the Phillips curve slope cannot be found at the episode-specific level makes it difficult for policy makers to know the potential costs of a disinflation.

This paper finds a negative relationship between past inflation history and the sacrifice ratio from episode-specific analysis and helps to reconcile the previously inconsistent findings. We measure inflation history using a geometric lag model of inflation. Including the inflation history variable along with traditional determinants of the sacrifice ratio, we find that the higher historical inflation has been the smaller the sacrifice ratio is during a disinflation.

The paper is organized as follows: in section 2, we construct a variable of inflation history with a geometric lag model. In section 3, we identify disinflation episodes in annual and quarterly data for seventeen Organization of Economic Co-operation and Development (OECD) countries and calculate the sacrifice ratios. We show that the sacrifice ratio depends on inflation history in section 4. Section 5 checks our findings by using alternative measures of the sacrifice ratio. Finally, section 6 concludes.

## II. INFLATION HISTORY AND THE COST OF REDUCING INFLATION

### *A. Motivation*

Ball et al. (1988) show that trend inflation influences the output-inflation tradeoff. Their finding has a practical implication for the conduct of monetary policy: by looking at the average rate of inflation, policy makers can improve their prediction of the cost of a disinflation. In countries with low inflation, the short-run Phillips curve will be flat and the sacrifice ratio will be large. In contrast, in countries with high inflation, the short-run Phillips curve will be steep and the sacrifice ratio will be small.

While the cross-country analysis strongly supports the prediction that higher inflation makes the short-run Phillips curve steeper, many researchers have asked if the same result holds in episode-specific analysis.[4] In the context of policy making, episode-specific evidence is more relevant than cross-country evidence. Cross-country evidence is often obtained by estimating a Phillips curve in a long time-series. Ball (1994) points out that this approach has two limitations. First, this approach constrains the slope of the Phillips curve to be constant across disinflations, reflations and temporary fluctuations in demand. Secondly, the Phillips-curve approach constrains the sacrifice ratio to be the same for all disinflations within a time series. An episode-specific approach enables us to examine the ratios within the experience of a country as well as across countries.

Ball (1994) shows that the negative effect of initial inflation on the sacrifice ratio is not robust once other determinants of the sacrifice ratio are included. A similar result is obtained by Andersen and Wascher (1999). Boschen and Weise (2001) obtain the wrong sign on their estimate. Hofstetter (2007) obtains coefficients with the expected sign but they are not statistically significant. Finally, Zhang (2005) finds, after allowing for long-lived output effects, there is indeed a significant and negative relationship between initial inflation and the sacrifice ratio. However, when the speed of disinflation is included in the regression, initial inflation becomes statistically insignificant. In sum, the results of the previous studies indicate that the effect of initial inflation on the sacrifice ratio is unclear. The question of why the effect of initial inflation is weaker than the effect of average inflation on the Phillips curve found by Ball et al. is still unsettled. The remainder of the paper attempts to reconcile the two seemingly inconsistent results.

### *B. Measuring Inflation History with a Geometric Lag Model*

In Ball et al.'s theoretical model, trend inflation (or average inflation) is related to the output-inflation tradeoff because average inflation influences the extent of nominal rigidity. When average inflation is higher, firms must adjust their prices more often to keep up with changes in the price level. That is, high average inflation leads firms to reduce the interval between price changes. This implies that in countries with high inflation, the Phillips curve is steeper and the sacrifice ratio is smaller.[5]

The link between inflation and the output-inflation trade-off is also established for the case in which a firm chooses to follow an (S,s) rule for adjusting its price. Tsiddon (1991) shows that higher average inflation reduces the real effect of a nominal shock if there is some persistence in inflation.

When one uses initial inflation as trend inflation, one implicitly assumes that firms will quickly adjust the interval (time) between price changes in response to the movement of actual inflation. The actual situation may be that firms adjust the interval between price changes based on a historical average of inflation rates and not on the current inflation rate. For example, a company that reviews prices once a year may not switch to reviewing prices twice a year unless it is certain that the change in trend inflation is permanent. Changes in actual inflation may be perceived as partly transitory and may evoke smaller changes in the frequency of price adjustment.

A natural step would be to use a weighted average of past inflation rates as a proxy for average (initial) inflation. The weighted average of past inflation is tractable because its calculation only requires information that is available contemporaneously to policy makers. The weighted average of inflation is described by a geometric lag model.

$$\begin{aligned} \pi_t^{IH} &= \sum_{i=1}^{\infty}(1-\lambda)\lambda^{i-1}\pi_{t-i} \\ &= (1-\lambda)\left[\pi_{t-1} + \lambda\pi_{t-2} + \lambda^2\pi_{t-3} + \cdots\right] \end{aligned} \tag{1}$$

where the parameter $\lambda$ is the adjustment coefficient. We will use the term "inflation history" to refer to $\pi^{IH}$ from equation (1).

The geometric lag model implies that the most recent past will receive the greatest weight and that the influence of past observations will fade uniformly with the passage of time. The model incorporates infinite lags, but it assigns arbitrarily small weights to the distant past. The lag coefficients decline geometrically; $w_i = (1-\lambda)\lambda^{i-1}$, $0 \le w_i < 1$. The mean lag is $\bar{w} = \frac{1}{1-\lambda}$. Since our focus is the effect of inflation history on the sacrifice ratio, we experiment with several values of the mean lag.

The idea of using inflation history as a determinant of sacrifice ratios is, to our knowledge, first proposed in Hofstetter (2007). In his study on disinflations in eighteen Latin-America and the Caribbean countries, Hofstetter defines inflation history as a simple average of the inflation rate of the past ten years, and examines the effect of inflation history on the sacrifice ratio. We elaborate over Hofstetter's definition of inflation and take the results a step further by exploiting them as a way to reconcile Ball et al.'s evidence with the seemingly insignificance of inflation as a determinant of sacrifice ratios.

## III. MEASURING THE SACRIFICE RATIO

The quarterly data for this study are drawn from a sample of nine countries and the annual data are from seventeen countries. The sample is from 1960 to 2002.[6] Quarterly inflation rates are calculated from the quarterly CPI level data and output is measured by real GDP.[7]

To identify the disinflation episodes, we borrow a technique from Ball (1994). Disinflations for each country are identified as follows. First, trend inflation, which is defined as a nine-quarter moving average of quarterly CPI inflation, is calculated. Second, the 'peaks' and ‘troughs’ in trend inflation are identified. Period *t* is an inflation peak if trend inflation at *t* is higher than in the previous four quarters and the following four quarters. Similarly, period *t* is a trough if trend inflation at *t* is lower than in the previous four quarters and the following four quarters. Finally, a disinflation is defined as one in which trend inflation declines by 2 percentage points or more from a peak. For annual data, a similar procedure is employed to identify disinflations (see Ball, 1994, p.166).

The 2% rule is intended to separate significant aggregate-demand policy shifts from smaller fluctuations arising from shocks. The application of the rule leads to a sample of thirty-six episodes with quarterly data and eighty episodes with annual data.[8] We have also checked the historical record (mainly by reading the OECD’s *Economic Outlook*) to see if each episode corresponds to a contractionary monetary policy. After checking the OECD’s *Economic Outlook*, we have excluded one episode from the quarterly data and three episodes from the annual data because we were not able to confirm that there was contractionary monetary policy near the start of the disinflation.[9] Therefore, the final number of episodes is thirty-five for quarterly data and seventy-seven for annual data.

The cost of a disinflation is measured with the sacrifice ratio, defined as the cumulative output gap over the disinflation period divided by the decline in trend inflation. Our measure of the output gap employs Ball’s (1994) method of computing trend output. Output is assumed to be at its trend level at the inflation peak and again at its trend level four quarters after the inflation trough. Trend output is determined by connecting the two points of the log of the output series. The output loss of the disinflation is the cumulative output gap from the inflation peak to four quarters following the inflation trough. Tables 1 and 2 list all the episodes and their sacrifice ratios. The average sacrifice ratio using Ball’s method is 1.65 in the quarterly data and 1.17 in the annual data. The ratio is positive in thirty-four of thirty-five cases for the quarterly data (column 5 in table 1) and in sixty-four of seventy-seven cases for the annual data (column 5 in table 2), suggesting that disinflation is usually costly.[10]

(<INSERT TABLE 1 HERE>)

(<INSERT TABLE 2 HERE>)

## IV. INFLATION HISTORY AS A DETERMINANT OF SACRIFICE RATIOS

We begin by examining the relationship between initial inflation and the sacrifice ratio in regressions similar to Ball's. Table 3 reports results from regressions of the sacrifice ratio on initial inflation, $\pi_0$. We also report results of regressions that include the length of the disinflation episode (Length) and the change in inflation over the disinflation ($\Delta\pi$). These independent variables are widely used as determinants of the sacrifice ratio. The length of the disinflation episode and the change in inflation are related to the speed of the disinflation.[11]

The results in table 3 are similar to those that are obtained by others. For quarterly data, the coefficient on initial inflation in the multiple regression is of the predicted sign but statistically insignificant. For annual data, the coefficient in regression 3.4 is not only insignificant but has the wrong sign.

(<INSERT TABLE 3 HERE>)

Next, following Hofstetter's definition of inflation history, we consider the results of regressions of the sacrifice ratio on inflation history with a mean lag of 40 quarters as the benchmark results. With a mean lag of 40 quarters, firms adjust the interval between price changes by looking at past inflation with the mean lag of 40 quarters (i.e., 10 years). Figure 1 present a scatter plot of sacrifice ratios and inflation history with a mean lag of 40 quarters.

The picture suggests the negative relationship as predicted by theory.

(<INSERT FIGURE 1 HERE>)

Table 4 reports the results. In these regressions, the coefficients on inflation history are of the predicted sign (negative), quantitatively large, and statistically significant, indicating that the sacrifice ratio is negatively related to inflation history. For the quarterly data, regression 4.2 implies that an increase in inflation history from five percent to ten percent reduces the sacrifice ratio by 1.08. The results for annual data are similar.[12] It is interesting to note that inflation history retains its significance even when both the change in inflation ($\Delta\pi$) and length of disinflation (*Length*) are in the regression. This result stands in sharp contrast to the results of previous studies where initial inflation often loses its statistical significance when both the change in inflation ($\Delta\pi$) and length of disinflation (*Length*) are in the regression.[13, 14]

(<INSERT TABLE 4 HERE>)

Table 5 presents the same regressions with smaller mean lag values. When firms adjust the interval between price changes, they consider past inflation with mean lags of 8 and 20 quarters. With a mean lag of 20 quarters, the regression results for both quarterly and annual data show a negative effect of inflation history on the sacrifice ratio, as predicted by theory. With a mean lag of 8 quarters, however, the results are not robust. The coefficient with a mean lag of 8 quarters for quarterly data is statistically significant, but the coefficient for annual data is not. It appears that the results with a mean lag of 8 quarters are weaker because in this version inflation history is too short.

(<INSERT TABLE 5 HERE>)

To clarify the implications of our regression results, table 6 presents the predicted average sacrifice ratios in the 1970s, the 1980s, and 2004. Average values of inflation history in the

1970s, the 1980s, and 2004 for the quarterly data are 4.86, 6.66, and 2.89, and for the annual data, 5.28, 7.83, and 3.47, respectively. We use regressions 4.2 and 4.4 and assume $\Delta\pi = 5.27$ and $Length = 13.8$ for the quarterly data and $\Delta\pi = 4.81$ and $Length = 13.5$ for the annual data. The results show that the effects of inflation history are not small. During the 1970s and 1980s in which we observe higher inflation history, the predicted sacrifice ratios are relatively small: 1.7 and 1.3 for quarterly data and 1.2 and 0.7 for annual data. In our present era of low inflation (and relatively low inflation history), the predicted sacrifice ratios are relatively large. The predicted ratios in 2004 are 2.2 for quarterly data and 1.5 for annual data. On average, the ratio in 2004 will be 61 percent larger than that in the 1980s for quarterly data and 108 percent larger for annual data.

(<INSERT TABLE 6 HERE>)

The results suggest that the slope of the Phillips curve (or the extent of nominal rigidity) depends on inflation history and that the slope of the Phillips curve changes as inflation history changes. These findings may provide an answer to the seemingly inconsistent evidence from earlier cross-country and episode-specific analyses.

## V. RESULTS USING ALTERNATIVE METHODS FOR MEASURING THE SACRIFICE RATIO

To check the robustness of the results, we use two new measures of the sacrifice ratio proposed by Zhang (2005) and Hofstetter (2007). Zhang's (2005) sacrifice ratio corrects for possible persistence effects and is based on the idea that recessions may affect output and unemployment even in the long run by changing the natural rate of output or unemployment. Zhang assumes that trend output is not required to be at its actual level four quarters after the inflation trough. In addition to persistence effects, Hofstetter's (2007) method takes into account inflation inertia, which implies that output may peak before inflation peaks. This sacrifice ratio allows the output losses to begin before the start of a disinflation episode. Columns 6 and 7 of tables 1 and 2 present Zhang's and Hofstetter's sacrifice ratios.

A couple of findings are worth discussing. First, Zhang and Hofstetter conjecture that, on average, Zhang's ratios are larger than Ball's and that Hofstetter's ratios are even larger than Zhang's. We see from the last row of tables 1and 2 that the average values for the three sacrifice ratios are consistent with their conjecture. Second, many authors argue that the costs of disinflation in the United States are higher than most OECD countries. Table 7 presents average sacrifice ratios by country. Except for Zhang's ratios for the quarterly data set, the sacrifice ratios in table 7 generally agree with the conventional view.

(<INSERT TABLE 7 HERE>)

The results using these alternative sacrifice ratios are presented in table 8 with inflation history calculated with a mean lag of 40 quarters. Examining regressions 8.1-8.4, the inflation history is significant in the annual regressions using Zhang's and Hofstetter's sacrifice ratios and support our earlier conclusion that inflation history helps determine the size of the sacrifice ratio. In the quarterly regressions, the relationship is weaker. In addition, Zhang (2005) finds that the sacrifice ratios calculated with his method for the 1990s are higher than other periods since potential output growth was lower in the 1990s than in previous decades. To account for the larger sacrifice ratios for the 1990s, we include a dummy variable, $D1990s$, that takes the value one if more than half of the observation's sample period falls in the 1990s and zero otherwise. For the quarterly data, the coefficient on inflation history for Zhang's sacrifice ratio is marginally significant at 0.102 (regression 8.5) and the coefficient for Hofstetter's sacrifice ratio is statistically significant at the 10 percent level (regression 8.7). For annual data, the coefficients on inflation history for Zhang's and Hofstetter's sacrifice ratios are significant at the 1 percent level (regression 8.6 and 8.8).

(<INSERT TABLE 8 HERE>)

Under both Zhang's and Hofstetter's assumptions, the results generally show a negative effect of inflation history on the sacrifice ratio and support the idea that measuring initial inflation by the inflation history variable gives a more accurate picture of the effect of inflation on the sacrifice ratio.

## VI. CONCLUSIONS

This paper has examined whether the episode-specific analysis produces the same effect of inflation on the Phillips curve that is found in cross-country analysis. While the relationship between inflation and the Phillips curve slope is widely accepted, it has not been conclusively shown in previous episode-specific studies. By defining inflation history as a weighted average of past inflation, this study finds a negative effect of inflation on the sacrifice ratio. The effect of inflation does not disappear even after other conventional determinants of the sacrifice ratio are included.

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TABLE 1

Disinflations: Quarterly Data

| Episode Year:Quarter | Length in Quarters | Initial Inflation | Change in Inflation | Sacrifice Ratio (Ball) | Sacrifice Ratio (Zhang) | Sacrifice Ratio (Hofstetter) |
|---|---|---|---|---|---|---|
| Australia | | | | | | |
| 60:2-62:3 | 9 | 3.23 | 3.19 | 3.4508 | 3.7244 | 1.1483 |
| 74:2-78:1 | 15 | 14.64 | 6.54 | 0.7256 | -0.6971 | 1.5387 |
| 82:1-84:1 | 8 | 10.45 | 4.95 | 1.4851 | 1.0698 | 0.9948 |
| 89:1-93:1 | 16 | 7.45 | 6.30 | 1.1530 | 2.4130 | 3.3974 |
| 95:2-98:1 | 11 | 3.65 | 3.10 | 0.2226 | -0.9196 | -1.0249 |
| Canada | | | | | | |
| 74:3-77:1 | 10 | 10.62 | 3.30 | 0.6440 | 1.5804 | 2.6983 |
| 81:2-85:2 | 16 | 11.49 | 7.66 | 2.1780 | 1.5913 | 0.5847 |
| 90:1-93:4 | 15 | 5.71 | 4.72 | 3.6811 | 3.4885 | 6.1782 |
| France | | | | | | |
| 74:3-77:1 | 10 | 11.89 | 2.98 | 2.0096 | 3.5646 | 4.7499 |
| 81:1-87:1 | 24 | 12.98 | 10.44 | 0.2827 | 0.1066 | 2.6070 |
| Germany | | | | | | |
| 65:4-67:3 | 7 | 3.39 | 2.10 | 2.3724 | 4.1391 | 3.8040 |
| 73:1-77:3 | 18 | 6.91 | 4.06 | 2.4549 | 6.5979 | 5.1633 |
| 81:1-86:3 | 22 | 5.92 | 5.93 | 1.8473 | 0.4084 | 5.3097 |
| Italy | | | | | | |
| 63:4-67:4 | 16 | 6.59 | 5.27 | 2.8539 | 0.7095 | -0.2655 |
| 80:4-87:3 | 27 | 18.99 | 14.42 | 1.1644 | 1.0905 | 4.1226 |
| 89:4-93:3 | 15 | 6.45 | 2.44 | 0.3224 | 6.0167 | 7.4864 |
| 95:1-98:3 | 14 | 4.62 | 2.88 | 0.8176 | 0.7967 | -4.5771 |
| Japan | | | | | | |
| 65:2-66:3 | 5 | 6.06 | 2.41 | 0.6332 | -0.6473 | 4.2871 |
| 70:2-71:3 | 5 | 7.19 | 1.82 | 1.1447 | 4.5181 | 4.4245 |
| 74:2-78:3 | 17 | 17.24 | 13.54 | 0.5100 | -0.0339 | 3.5238 |
| 80:2-87:1 | 27 | 6.72 | 6.72 | 2.3557 | 2.3200 | 5.3381 |
| 90:2-96:1 | 23 | 3.65 | 3.78 | 1.6344 | 13.0671 | 12.5091 |
| Switzerland | | | | | | |
| 66:2-68:4 | 10 | 4.51 | 2.30 | 3.2828 | 3.4811 | 6.2006 |
| 73:4-77:4 | 16 | 9.47 | 8.43 | 1.7698 | 4.2944 | 5.7024 |
| 81:3-83:4 | 9 | 6.08 | 3.59 | 1.8988 | 3.0277 | 2.5861 |
| United Kingdom | | | | | | |
| 61:2-63:3 | 9 | 3.94 | 1.63 | 3.4266 | 3.1011 | 1.8780 |
| 65:2-66:3 | 5 | 4.74 | 2.10 | -0.0671 | 0.9367 | 3.4421 |
| 75:1-78:2 | 13 | 19.55 | 9.70 | 0.9899 | -0.0917 | 0.1335 |
| 80:2-83:3 | 13 | 15.55 | 11.26 | 0.5841 | -0.0590 | 2.4064 |
| 84:2-86:3 | 9 | 6.18 | 3.02 | 0.6979 | -1.5452 | -3.1528 |
| 89:2-93:3 | 17 | 8.77 | 7.06 | 1.8438 | 3.4601 | 5.0868 |
| United States | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 69:4-71:4 | 8 | 5.53 | 1.90 | 2.8941 | 1.2915 | 4.4151 |
| 74:2-76:4 | 10 | 9.65 | 3.87 | 1.9094 | 1.5822 | 5.1382 |
| 80:1-83:4 | 15 | 11.92 | 8.59 | 1.9284 | 1.3998 | 2.9451 |
| 89:4-94:3 | 19 | 5.18 | 2.57 | 2.6751 | 3.5318 | 7.4164 |
| Average | 13.8 | 8.48 | 5.27 | 1.6508 | 2.2661 | 3.3770 |

## TABLE 2
## Disinflations: Annual Data

| Episode Years | Length in Years | Initial Inflation | Change in Inflation | Sacrifice Ratio (Ball) | Sacrifice Ratio (Zhang) | Sacrifice Ratio (Hofstetter) |
|---|---|---|---|---|---|---|
| Australia | | | | | | |
| 60-62 | 2 | 3.39 | 3.43 | 1.6759 | 2.3242 | 1.2077 |
| 74-78 | 4 | 14.81 | 6.70 | 0.5358 | 1.9578 | 4.3288 |
| 82-84 | 2 | 10.54 | 5.35 | 1.0648 | 0.0118 | 1.5624 |
| 86-88 | 2 | 8.58 | 1.44 | -0.1963 | -5.4515 | -2.6847 |
| 89-92 | 3 | 7.43 | 5.89 | 0.7356 | 3.1695 | 2.1882 |
| 95-97 | 2 | 3.75 | 3.24 | 0.3645 | -0.9587 | -1.4960 |
| Austria | | | | | | |
| 64-66 | 2 | 4.52 | 2.32 | 0.0234 | 2.4627 | 0.9869 |
| 74-78 | 4 | 8.89 | 5.50 | 1.4671 | 4.7989 | 5.6368 |
| 80-82 | 2 | 6.49 | 2.28 | 1.2540 | 3.4520 | 4.4294 |
| 84-86 | 2 | 4.75 | 3.34 | -0.1654 | -0.1129 | 1.9413 |
| 92-98 | 6 | 3.85 | 3.20 | 2.5513 | 6.0375 | 9.5141 |
| Belgium | | | | | | |
| 65-67 | 2 | 4.71 | 2.62 | 0.5208 | 2.7254 | 3.9511 |
| 74-78 | 4 | 11.99 | 7.77 | 0.5991 | 3.7497 | 4.1309 |
| 82-87 | 5 | 8.17 | 6.87 | 1.5925 | 0.1217 | 1.8341 |
| Canada | | | | | | |
| 68-70 | 2 | 4.34 | 1.42 | 0.2779 | 3.0237 | 2.9244 |
| 74-76 | 2 | 10.23 | 2.36 | 0.4088 | 1.8225 | 3.0674 |
| 81-85 | 4 | 11.54 | 7.67 | 1.9028 | 2.4378 | 2.4429 |
| 90-93 | 3 | 5.31 | 4.43 | 2.3432 | 4.0099 | 7.2300 |
| Denmark | | | | | | |
| 62-64 | 2 | 7.49 | 4.35 | 0.9403 | 1.3358 | 0.9542 |
| 67-69 | 2 | 8.21 | 4.22 | -0.3896 | -0.3880 | 0.6895 |
| 74-76 | 2 | 12.47 | 3.51 | 0.8108 | 1.4445 | 6.4552 |
| 80-86 | 6 | 12.52 | 8.92 | 1.1825 | -0.2392 | 1.7512 |
| 88-90 | 2 | 4.60 | 2.09 | 0.4605 | 2.8545 | 3.7354 |
| Finland | | | | | | |
| 63-65 | 2 | 7.68 | 3.58 | -0.7771 | 0.4364 | 2.6375 |
| 67-69 | 2 | 7.50 | 5.16 | 0.9513 | -0.9043 | 1.0966 |
| 74-78 | 4 | 16.73 | 9.16 | 1.4451 | 4.1245 | 5.2015 |
| 80-86 | 6 | 11.46 | 8.00 | 0.6415 | 1.0985 | -0.7444 |
| 89-94 | 5 | 6.21 | 5.26 | 4.9220 | 13.6548 | 10.7139 |
| France | | | | | | |
| 62-66 | 4 | 5.27 | 2.94 | -0.8334 | 2.0574 | 0.3903 |
| 74-77 | 3 | 12.29 | 3.17 | 1.5359 | 5.0248 | 7.5832 |
| 81-86 | 5 | 12.66 | 9.79 | 0.2289 | 0.8871 | 1.9620 |
| 89-94 | 5 | 3.36 | 1.70 | -0.9339 | 9.7659 | 1.6474 |
| Germany | | | | | | |
| 65-67 | 2 | 3.59 | 2.08 | 1.2167 | 7.1481 | 7.7872 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 73-78 | 5 | 7.03 | 3.93 | 3.8602 | 7.6157 | 6.4032 |
| 80-86 | 6 | 5.71 | 5.71 | 1.9075 | 4.3354 | 6.5428 |
| Italy | | | | | | |
| 63-67 | 4 | 6.35 | 4.71 | 2.4052 | 2.5524 | 4.1631 |
| 74-78 | 4 | 16.90 | 4.57 | 2.7850 | 4.5833 | 4.7737 |
| 80-87 | 7 | 19.34 | 14.69 | 1.3675 | 2.7651 | 2.8205 |
| 90-93 | 3 | 6.17 | 2.04 | 0.1900 | 5.6762 | 6.6502 |
| 95-98 | 3 | 4.78 | 3.04 | 0.2182 | -0.0235 | -2.0068 |
| Japan | | | | | | |
| 62-64 | 2 | 7.88 | 2.72 | 3.0063 | -0.1684 | 1.6347 |
| 65-66 | 1 | 5.99 | 2.02 | -0.0065 | 0.5279 | -8.0107 |
| 70-71 | 1 | 7.21 | 1.58 | 1.2315 | 5.1808 | 6.2659 |
| 74-78 | 4 | 16.84 | 13.16 | 0.4012 | 1.4201 | 5.4237 |
| 80-87 | 7 | 6.33 | 6.14 | 1.8427 | 1.8360 | 2.9476 |
| 90-95 | 5 | 2.92 | 2.87 | 0.3814 | 10.1301 | 9.1722 |
| Netherlands | | | | | | |
| 65-67 | 2 | 5.45 | 2.25 | 1.5283 | 2.7806 | 2.2713 |
| 75-78 | 3 | 9.59 | 5.80 | -1.1905 | 0.0799 | 3.7189 |
| 80-86 | 6 | 6.32 | 6.75 | 2.7422 | 3.6974 | 2.8362 |
| 91-97 | 6 | 3.64 | 1.60 | 6.7827 | 8.6842 | 9.8904 |
| New Zealand | | | | | | |
| 75-78 | 3 | 15.26 | 3.50 | 1.7857 | 6.7654 | 8.9276 |
| 80-83 | 3 | 15.54 | 9.19 | 0.5360 | -0.6504 | -0.2494 |
| 86-88 | 2 | 13.95 | 8.67 | -0.9102 | -1.5393 | -1.9296 |
| 89-92 | 3 | 5.90 | 4.76 | 2.1432 | 3.9284 | 6.3406 |
| 94-98 | 4 | 3.29 | 2.63 | -0.9996 | -0.2841 | -6.4701 |
| Norway | | | | | | |
| 75-78 | 3 | 10.43 | 4.15 | -0.6988 | -1.6968 | -1.2781 |
| 81-85 | 4 | 12.06 | 6.35 | 1.3086 | 0.9765 | 3.9420 |
| 87-93 | 6 | 8.16 | 6.46 | 3.2839 | 4.4541 | 5.9713 |
| Sweden | | | | | | |
| 66-68 | 2 | 5.86 | 3.71 | 0.4160 | 0.7407 | 3.1470 |
| 76-78 | 2 | 10.59 | 2.33 | 2.6534 | 4.8226 | 7.2063 |
| 80-82 | 2 | 12.64 | 4.28 | 0.4105 | 1.4527 | 1.2772 |
| 83-86 | 3 | 8.38 | 4.78 | -0.3431 | -2.3657 | -2.4804 |
| 90-97 | 7 | 9.81 | 9.64 | 3.0785 | 4.1856 | 4.7500 |
| Switzerland | | | | | | |
| 66-68 | 2 | 4.41 | 1.87 | 1.3457 | 1.9393 | 6.7987 |
| 74-77 | 3 | 8.67 | 7.29 | 1.7712 | 5.5145 | 6.6030 |
| 81-83 | 2 | 5.81 | 2.60 | 1.7029 | 3.1945 | 2.4276 |
| 84-86 | 2 | 3.24 | 2.28 | -1.1593 | -1.7399 | -4.5523 |
| 90-94 | 4 | 5.46 | 4.20 | 0.7780 | 6.6474 | 4.3678 |
| United Kingdom | | | | | | |
| 61-63 | 2 | 4.23 | 1.99 | 2.0298 | -0.2391 | 0.5085 |
| 74-78 | 4 | 18.73 | 9.89 | 0.6897 | 0.6794 | 3.2824 |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| 80-83 | 3 | 15.66 | 11.26 | 0.6003 | 0.5994 | 2.2481 |
| 84-86 | 2 | 5.95 | 2.51 | 0.3458 | -3.5961 | -4.6869 |
| 89-93 | 4 | 8.66 | 6.74 | 1.6879 | 4.1455 | 4.7020 |
| United States |  |  |  |  |  |  |
| 69-71 | 2 | 5.62 | 1.89 | 2.6954 | 5.1506 | 7.6797 |
| 74-76 | 2 | 9.76 | 3.47 | 1.4123 | 1.1134 | 5.5845 |
| 79-83 | 4 | 12.02 | 8.24 | 1.9774 | 2.9463 | 2.8568 |
| 89-94 | 5 | 4.82 | 2.11 | 4.1103 | 11.1677 | 10.5013 |
| Average | 3.36 | 8.42 | 4.81 | 1.1748 | 2.6476 | 3.2212 |

TABLE 3

The Sacrifice Ratio and Initial Inflation

(dependent variable: Ball's sacrifice ratio)

| | 3.1<br>Quarterly | 3.2<br>Quarterly | 3.3<br>Annual | 3.4<br>Annual |
|---|---|---|---|---|
| Constant | 2.399*** | 2.125*** | 1.332*** | -0.090 |
| | (0.352) | (0.559) | (0.369) | (0.450) |
| $\pi_0$ | -0.088** | -0.095 | -0.019 | 0.047 |
| | (0.037) | (0.076) | (0.039) | (0.056) |
| $\Delta\pi$ | | -0.005 | | -0.195** |
| | | (0.121) | | (0.092) |
| *Length* | | 0.026 | | 0.134*** |
| | | (0.040) | | (0.029) |
| $\overline{R}^2$ | .122 | .086 | -.010 | .198 |
| Sample | 35 | 35 | 77 | 77 |

*Note:* Standard errors are in parentheses. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

TABLE 4

The Sacrifice Ratio and Inflation History (Mean Lag = 40 quarters)

(dependent variable: Ball's sacrifice ratio)

| | 4.1 | 4.2 | 4.3 | 4.4 |
|---|---|---|---|---|
| | Quarterly | Quarterly | Annual | Annual |
| Constant | 2.693*** | 2.247*** | 1.804*** | 0.722* |
| | (0.365) | (0.436) | (0.391) | (0.404) |
| $\pi^{IH}$ | -0.201*** | -0.216*** | -0.118* | -0.180*** |
| | (0.064) | (0.074) | (0.067) | (0.065) |
| $\Delta\pi$ | | -0.064 | | -0.075 |
| | | (0.062) | | (0.060) |
| *Length* | | 0.063* | | 0.132*** |
| | | (0.033) | | (0.026) |
| $\overline{R}^2$ | .208 | .246 | .027 | .266 |
| Sample | 35 | 35 | 77 | 77 |

*Note:* Standard errors are in parentheses. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

TABLE 5

The Sacrifice Ratio and Inflation History (Mean Lag = 8 and 20 quarters)

(dependent variable: Ball's sacrifice ratio)

| | Mean Lag = 8 quarters | | Mean Lag = 20 quarters | |
|---|---|---|---|---|
| | 5.1 | 5.2 | 5.3 | 5.4 |
| | Quarterly | Annual | Quarterly | Annual |
| Constant | 2.301*** | 0.243 | 2.276*** | 0.633 |
| | (0.517) | (0.458) | (0.458) | (0.421) |
| $\pi^{IH}$ | -0.184* | -0.028 | -0.204** | -0.143** |
| | (0.092) | (0.076) | (0.078) | (0.068) |
| $\Delta\pi$ | 0.050 | -0.109 | -0.004 | -0.045 |
| | (0.110) | (0.091) | (0.076) | (0.071) |
| *Length* | 0.021 | 0.122*** | 0.043 | 0.120*** |
| | (0.037) | (0.029) | (0.033) | (0.027) |
| $\overline{R}^2$ | .150 | .192 | .215 | .237 |
| Sample | 35 | 77 | 35 | 77 |

*Note:* Standard errors are in parentheses. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

TABLE 6

Predicted Average Sacrifice Ratios in the 1970s and 1980s vs. Present

| Predicted Average Sacrifice Ratios | Quarterly | Annual |
|---|---|---|
| 1970s | 1.7 | 1.2 |
| 1980s | 1.3 | 0.7 |
| 2004 | 2.2 | 1.5 |

Source: Authors' calculations based on regression equations 4.2 and 4.4 from table 4.

*Note:* These figures assume the change in inflation, $\Delta\pi$, for the quarterly and annual data are 5.27 and 4.81, and the episode length, $Length$, are 13.8 and 13.5 quarters, respectively.

## TABLE 7
Average Sacrifice Ratio by Country

| | Quarterly | | | Annual | | |
|---|---|---|---|---|---|---|
| | Ball | Zhang | Hofstetter | Ball | Zhang | Hofstetter |
| Australia | 1.41 | 1.12 | 1.21 | 0.70 | 0.18 | 0.85 |
| Austria | | | | 1.03 | 3.33 | 4.50 |
| Belgium | | | | 0.90 | 2.20 | 3.31 |
| Canada | 1.76 | 2.07 | 3.36 | 1.23 | 2.82 | 3.92 |
| Denmark | | | | 0.60 | 1.00 | 2.72 |
| Finland | | | | 1.44 | 3.68 | 3.78 |
| France | 1.15 | 1.84 | 3.68 | 0.00 | 4.43 | 2.90 |
| Germany | 2.22 | 3.72 | 4.76 | 2.33 | 6.37 | 6.91 |
| Italy | 1.29 | 2.15 | 1.69 | 1.39 | 3.11 | 3.28 |
| Japan | 1.26 | 3.84 | 6.02 | 1.14 | 3.15 | 2.91 |
| Netherlands | | | | 2.47 | 3.81 | 4.68 |
| New Zealand | | | | 0.51 | 1.64 | 1.32 |
| Norway | | | | 1.30 | 1.24 | 2.88 |
| Sweden | | | | 1.24 | 1.77 | 2.78 |
| Switzerland | 2.32 | 3.60 | 4.83 | 0.89 | 3.11 | 3.13 |
| United Kingdom | 1.25 | 0.97 | 1.63 | 1.07 | 0.32 | 1.21 |
| United States | 2.35 | 1.95 | 4.98 | 2.55 | 5.09 | 6.66 |

Source: Authors’ calculations.

TABLE 8

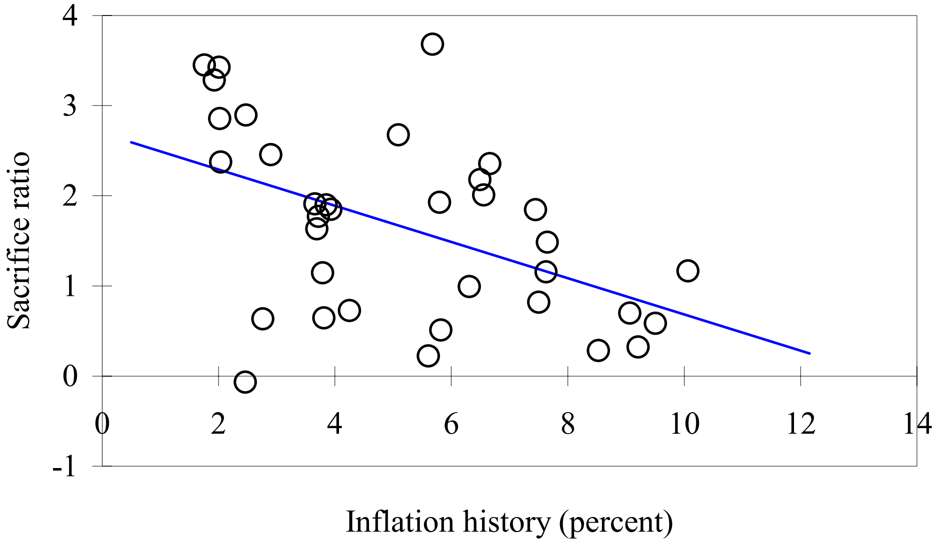
The Sacrifice Ratio and Inflation History (Mean Lag = 40 quarters)

(dependent variable: Zhang's or Hofstetter's sacrifice ratios)

| | Zhang's Sacrifice Ratio | | Hofstetter's Sacrifice Ratio | | Zhang's Sacrifice Ratio | | Hofstetter's Sacrifice Ratio | |
|---|---|---|---|---|---|---|---|---|
| | 8.1 Quarterly | 8.2 Annual | 8.3 Quarterly | 8.4 Annual | 8.5 Quarterly | 8.6 Annual | 8.7 Quarterly | 8.8 Annual |
| Constant | 1.948* | 1.627* | 2.352* | 2.763** | 2.274* | 2.149** | 2.619* | 3.114*** |
| | (1.148) | (0.929) | (1.386) | (1.158) | (1.148) | (0.880) | (1.413) | (1.160) |
| $\pi^{IH}$ | -0.219 | -0.280* | -0.391 | -0.463** | -0.366 | -0.445*** | -0.511* | -0.574*** |
| | (0.196) | (0.151) | (0.237) | (0.188) | (0.217) | (0.149) | (0.267) | (0.196) |
| $\Delta\pi$ | -0.431** | -0.417*** | -0.219 | -0.122 | -0.270 | -0.183 | -0.087 | 0.035 |
| | (0.162) | (0.138) | (0.196) | (0.172) | (0.193) | (0.146) | (0.237) | (0.192) |
| *Length* | 0.270*** | 0.336*** | 0.305*** | 0.262*** | 0.211** | 0.231*** | 0.257** | 0.191** |
| | (0.086) | (0.060) | (0.104) | (0.075) | (0.094) | (0.064) | (0.115) | (0.084) |
| *D1990s* | | | | | 1.757 | 2.978*** | 1.440 | 1.999* |
| | | | | | (1.191) | (0.868) | (1.466) | (1.143) |
| $\overline{R}^2$ | .246 | .295 | .176 | .153 | .273 | .386 | .175 | .176 |
| Sample | 35 | 77 | 35 | 77 | 35 | 77 | 35 | 77 |

*Note:* Standard errors are in parentheses. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

## Figure 1
## Sacrifice Ratios and Inflation History with a Mean Lag of 40 Quarters (from Regression 4.1 in Table 4)



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[*] We would like to thank Laurence Ball, Steven Yamarik and three anonymous referees for useful comments.

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[1] Among them, the traditional determinants that are consistently included in the empirical literature are the initial level of inflation (Ball, Mankiw, and Romer 1988), the speed of the disinflation (Ball 1994), an index of nominal wage rigidity (Bruno and Sachs 1985), and the openness of the economy (Romer 1993).

[2] Their findings are confirmed by DeFina (1991) and Kiley (2000).

[3] This puzzle is first reported by Ball (1994) and later by Boschen and Weise (2001), and Zhang (2005). This paper builds on Hofstetter (2007) who proposes measuring inflation history using inflation over the previous 10 years.

[4] See Ball (1994); Andersen and Wascher (1999); Boschen and Weise (2001); Hofstetter (2007);

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Zhang (2005) for more details.

[5] For further details of a negative relationship between average inflation and the sacrifice ratio, see Bonomo and Carvalho (2004).

[6] The inflation and output data from 1957:1 to 2005:3 are used to construct trend inflation and the filtered output series.

[7] The data on inflation and output are from the International Monetary Fund's *International Financial Statistics* (*IFS*). Japan's seasonally adjusted quarterly output data, which are not available in *IFS*, are taken from the Cabinet Office, Government of Japan.

[8] Due to data revisions, several disinflations that were identified in Ball's (1994) paper no longer comply with the criteria imposed by the rule. However, because these disinflations are very close to the criteria and the episodes match known monetary policy contractions, we retain them in our sample to make our results comparable with Ball's. For the quarterly data, we include Japan, 1970:2-71:3 (in which trend inflation declined 1.82%), the United Kingdom, 1961:2-63:3 (1.63%), and the United States, 1969:4-71:4 (1.90%). For the annual data, we include Australia, 1986-88 (in which trend inflation declined 1.44%) and Canada, 1968-1970 (1.42%).

[9] The excluded episodes are: Japan 1997:2-2001:1 (quarterly), Austria 1961-63 (annual), Japan 1997-01 (annual), and Norway 1964-66 (annual).

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[10] In the quarterly data, we have the same countries as Ball (1994) but in the annual data we have different countries. We excluded Spain, Luxemburg and Ireland in the annual data because we couldn't verify that disinflations in those countries were associated with monetary policy tightening.

Our sample of sacrifice ratios is also slightly different from Ball's and we think that this is due to data revisions to real GDP. For the quarterly data, the correlation between the twenty-four matched episodes of Ball's and our sacrifice ratios is .78. For the annual data, the correlation between the fifty-two matched episodes is .72.

[11] We have also estimated the regressions with Bruno and Sachs's wage rigidity index and an openness variable. These variables are never significant so they are dropped.

[12] Inflation history in the annual regressions is based on quarterly data which are subsequently aggregated to an annual frequency. Therefore, the mean lag of 40 quarters in the quarterly regressions is equivalent to a mean lag of 10 years in the annual regressions.

[13] It is possible that this study's findings are affected by inflation targeting. To check whether inflation targeting has an effect on the results, we have also used a sample from which the inflation targeting disinflation episodes are excluded. The coefficients on the inflation history variable estimated without the inflation targeting disinflation episodes are similar to those

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reported.

[14] As discussed in footnote 4, we included a few disinflations that do not follow the 2% rule. When we estimate regressions 4.2 and 4.4 without those disinflation episodes, we find that

(Quarterly)
$$\underset{}{Sacrifice\ Ratio} = \underset{(0.486)}{2.022} - \underset{(0.076)}{0.192}\,\pi^{IH} - \underset{(0.062)}{0.057}\,\Delta\pi + \underset{(0.034)}{0.063}\,Length$$

$$\overline{R}^2 = .200 \qquad sample\ size = 32$$

(Annual)
$$Sacrifice\ Ratio = \underset{(0.415)}{0.795} - \underset{(0.068)}{0.180}\,\pi^{IH} - \underset{(0.061)}{0.082}\,\Delta\pi + \underset{(0.026)}{0.131}\,Length$$

$$\overline{R}^2 = .261 \qquad sample\ size = 75$$

The results are little affected by the exclusion of those episodes.

Abbreviations

$\pi_0$: initial inflation (percent)

*Length*: length of disinflation episode

$\Delta\pi$ : change in inflation over the disinflation (percentage points)

$\pi^{IH}$ : inflation history (percent)

*D1990s*: dummy variable equal to 1 if more than half of the observation's sample period falls in the 1990s and 0 otherwise