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Can Higher Inflation Be More Stable? Evidence from Japan and the US

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Abstract

This paper investigates the relationship between trend inflation and inflation volatility. Using annual data from 1922 to 2013, the results show that Japanese and US inflation and its volatility have been positively correlated when inflation exceeds a certain value, but negatively correlated when inflation is below this threshold. The evidence suggests that the break in the relationship occurs at annual inflation rates around 2.5% in the US and between 0% and 2% in Japan. This implies that inflation exceeding 2.5% in the US or 2% in Japan is likely to be associated with higher inflation volatility.

Keywords: Inflation, Inflation Volatility, Trend Inflation

JEL classification: E31, E32

1. Introduction

In the aftermath of the 2007-2009 global financial crisis, both Japan and the US have been urged to consider higher inflation targets in the belief that this will prove stabilizing. The main argument is that higher inflation will weaken the constraints imposed on monetary policy by the zero lower bound for nominal interest rates.[1] Of course, any such benefits must be weighed against the well-known costs of higher inflation, which include those stemming from higher inflation volatility. Is it realistic to expect the benefits of higher inflation to outweigh the costs? If so, how much should the target be raised? These are the topics of the present paper.

One of the main reasons inflation is destabilizing, is that higher inflation tends to also be more volatile inflation. In fact, the relationship between inflation and its volatility plays a central role in important macroeconomic questions involving monetary policy and the costs of inflation. Despite the scarcity of theoretical models explaining this relationship,[2] there is widespread consensus that the level of inflation and inflation volatility are strongly and positively correlated. Originally, the positive relationship was considered mostly at higher inflation rates, as in Friedman (1977). Gradually, however, the positive correlation was extended to apply to moderate or even low

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[1] See for example Blanchard, Dell'Ariccia, and Mauro (2010), Ball (2013), English, López-Salido, and Telow (2013), and The Economist (2013) .

[2] Ball (1992) and Kiley (2007) provide two influential exceptions.

inflation rates (for example Kiley, 2007), so that eventually the relationship has come to be thought of as monotonic. Put simply, high inflation is generally expected to be variable inflation, while conversely low inflation is generally expected to be stable inflation.

Recently, however, Coibion, Gorodnichenko, and Wieland (2012) have presented a theoretical New Keynesian model that not only endogenously generates a relationship between the level and volatility of inflation, but also predicts that this relationship is not monotonic. In particular, their model predicts that the relationship between the level and volatility of inflation is negative at low levels of inflation, becoming positive only when inflation rises above a specific value. Coibion, Gorodnichenko, and Wieland (2012) compute that the break in the relationship occurs at annual inflation of 3.5%. In the rest of the present paper, we refer to this as the CGW Hypothesis.

The significance of such a result for monetary policy is straightforward. Suppose that inflation and its volatility are indeed negatively related when inflation is below a certain threshold. This would then mean that if inflation falls below that threshold, raising it would make inflation more stable – indeed, it would mean that inflation would have to be raised in order to be made more stable.

The goal of this paper is to examine empirically the relationship between inflation and its volatility and test the CGW Hypothesis. Using annual Japanese and US data over the period 1922-2013, the paper estimates the relationship between trend (or average) inflation and inflation volatility.

Our first finding with this data set is that the overall correlation between inflation and its volatility is extremely low. Next, we ask whether the 3.5% inflation value implied by the model of Coibion, Gorodnichenko, and Wieland (2012) really marks a break point in the relationship, and we find that it does: for inflation values higher than 3.5%, the correlation between inflation and its volatility has been positive; while for inflation below 3.5%, the correlation is negative. This is consistent with the CGW Hypothesis.

But is 3.5% the actual break point? To answer that, we use a quadratic model to estimate the break point. The empirical results suggest a break point around 2.5% for the US and between 0% and 2% for Japan. For the US, the policy implication is that reducing inflation below 2.5% may make it less, rather than more, stable. Inflation exceeding 2.5% in the US or 2% in Japan, however, is likely to be associated with higher inflation volatility.

The rest of the paper is organized as follows. Section 2 discusses the data and defines the variables to be used in the estimation. Section 3 outlines the estimation methodology, derives the main empirical results, and implements a number of robustness checks. Section 4 discusses the findings and concludes.

2. The Data

The price level (P_t) is measured by the Consumer Price Index (CPI). The source is Mitchell (1998), updated using data from the OECD, and the data sets consist of annual observations covering the period 1922 – 2013. The inflation rate (π_t) is defined as the percent change in the CPI: $\pi_t = 100 \cdot (P_t - P_{t-1})/P_{t-1}$.[3]

Time-varying *average inflation* ($\bar{\pi}_t$) and *inflation volatility* (σ_t^π) series are constructed using rolling five-year windows: $\bar{\pi}_t$ and σ_t^π are set equal to the mean and standard deviation,

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[3] The CPI price levels and inflation rates of both countries were tested for stationarity using the Dickey-Fuller (1979) and Phillips-Perron (1988) unit root tests. The results are reported in the Appendix. It is apparent that the CPI price level is not stationary in either country, whereas the inflation rate is stationary in both countries. I wish to thank an anonymous referee of this journal for recommending the tests.

respectively, of the inflation rate over each 5-year period.[4] In addition, we use the Hodrick-Prescott (HP) filter, proposed by Hodrick and Prescott (1980, 1997), to decompose inflation into permanent and transitory components. We set the *trend inflation* series ($\overline{\pi}_t^{HP}$) equal to the HP permanent component, and we use again rolling five-year windows to define our second measure of *inflation volatility* (σ_t^{HP}) as the standard deviation of the HP transitory component of the inflation rate over each five-year period.[5]

Figures 1 – 3 present inflation (π_t), average inflation ($\overline{\pi}_t$), the HP trend inflation ($\overline{\pi}_t^{HP}$), and inflation volatility (σ_t^{π}), for the US and Japan over 1923 – 2013. Figure 1 plots the US series, clearly showing that periods of high trend (or average) inflation have also been periods of elevated inflation volatility. At the same time, however, periods of unusually low (including negative) inflation also tend to be periods of high volatility. Figure 2 plots the Japanese series, but the relationships among them are not easy to visualize as the sample is so much dominated by the extremely high values of the Word War II period. To render the Japanese patterns more visible, Figure 3 plots again the Japanese series, excluding years with inflation higher than 30%. Periods of high trend (or average) inflation are again seen to have been periods of elevated inflation volatility. Once more, however, periods of unusually low (including negative) inflation also tend to be periods of high volatility, just as in the US.

Figures 1 and 3, therefore, suggest that while very high inflation has been volatile inflation in both countries, so may have been very low inflation. This raises the possibility that the relationship between inflation and inflation volatility is nonlinear, a hypothesis that is more formally examined in the next section.

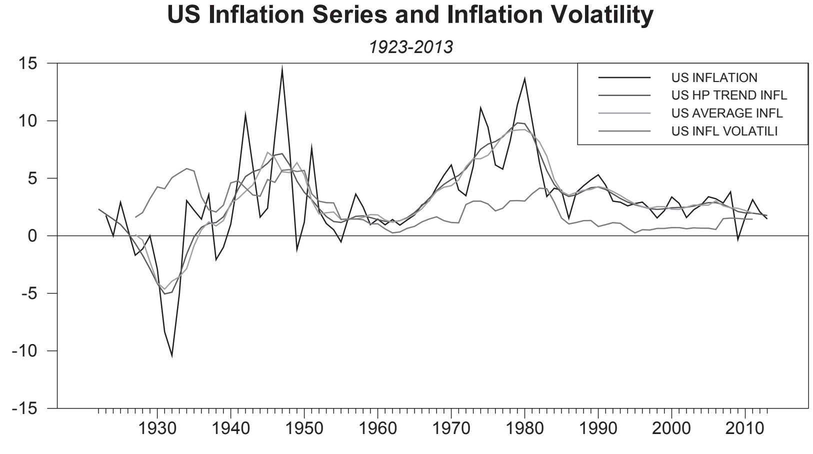

Figure 1.

Inflation (π_t), Average Inflation ($\overline{\pi}_t$), HP Trend Inflation (π_t^{HP}), and Inflation Volatility (σ_t^{π})

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[4] Middle-of-window values are used for both $\overline{\pi}_t$ and σ_t^{π}.

[5] In particular, the HP filter defines the trend, $\overline{\pi}_t^{HP}$, as the component that minimizes

$$\sum_{t=1}^{T}\left(\pi_t - \overline{\pi}_t^{HP}\right)^2 + \lambda\sum_{t=2}^{T-1}\left[\left(\overline{\pi}_{t+1}^{HP} - \overline{\pi}_t^{HP}\right) - \left(\overline{\pi}_t^{HP} - \overline{\pi}_{t-1}^{HP}\right)\right]^2$$

for $\lambda > 0$. In the empirical section below we report results for $\lambda = 6.25$, as recommended by Ravn and Uhlig (2002), but we have also tried $\lambda = 100$, the value suggested by Hodrick and Prescott for annual data.

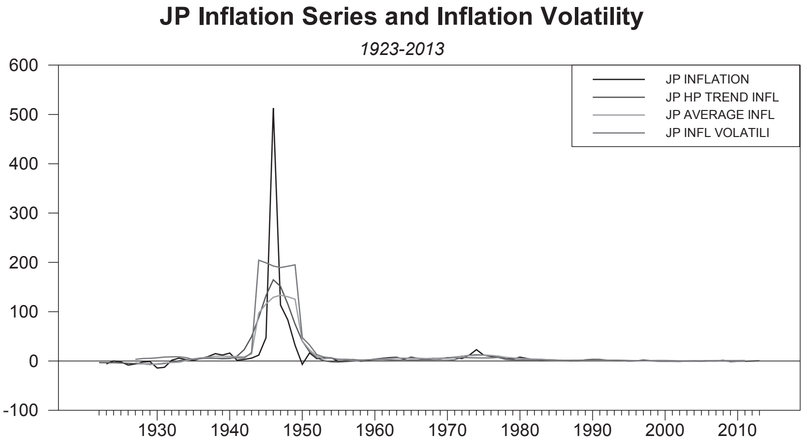

Figure 2.

Inflation (π_t), Average Inflation ($\bar{\pi}_t$), HP Trend Inflation (π_t^{HP}), and Inflation Volatility (σ_t^{π})

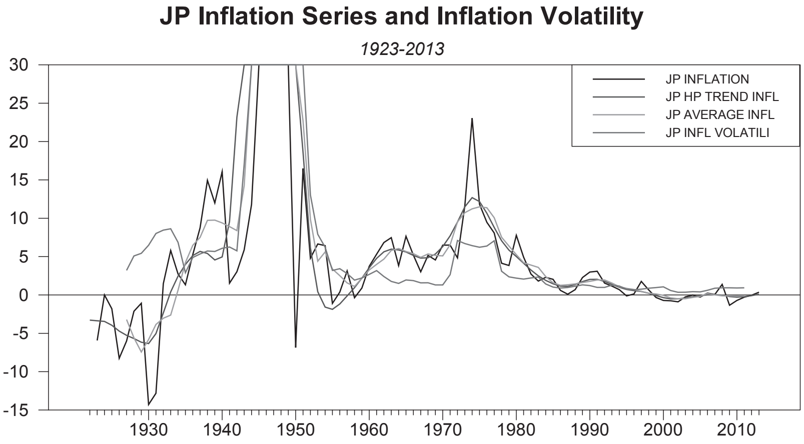

Figure 3.

Inflation (π_t), Average Inflation ($\bar{\pi}_t$), HP Trend Inflation (π_t^{HP}), and Inflation Volatility (σ_t^{π})

3. Empirical Evidence

3.1. Linear Relationship

We start with a simple linear relationship between inflation volatility and trend inflation, of the form:

$$\hat{\sigma}_t^{\pi} = \alpha + \beta \cdot \hat{\pi}_t + u_t , \qquad (1)$$

where $\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$ or σ_t^{HP}; and $\hat{\pi}_t = \bar{\pi}_t$, or $\bar{\pi}_t^{HP}$. Table 1 reports the estimated βs, as well as the correlation coefficients between $\hat{\sigma}_t^{\pi}$ and $\hat{\pi}_t$.[6] As expected, the βs are all positive, though they are

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[6] For this, as well as all the following empirical specifications, the Japanese sample excludes inflation values that exceed 30% to avoid obtaining results that are dominated by the very few but extremely high World War II inflation values. This eliminates the influence of these outliers, making the results comparable with those obtained for the US and more relevant for the inflation experience that characterizes the overwhelming majority of the sample period.

Table 1

Linear Relationships

$$\hat{\sigma}_t^{\pi} = \alpha + \beta \cdot \hat{\pi}_t + u_t$$

	US			JAPAN		
	$\hat{\sigma}_t^{\pi} = \sigma_t^{HP}$		$\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$	$\hat{\sigma}_t^{\pi} = \sigma_t^{HP}$		$\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$
	$\hat{\pi}_t = \overline{\pi}_t^{HP}$	$\hat{\pi}_t = \overline{\pi}_t$	$\hat{\pi}_t = \overline{\pi}_t^{HP}$	$\hat{\pi}_t = \overline{\pi}_t^{HP}$	$\hat{\pi}_t = \overline{\pi}_t$	$\hat{\pi}_t = \overline{\pi}_t^{HP}$
β	0.049 (0.047)	0.045 (0.049)	0.033 (0.058)	0.622** (0.120)	0.749** (0.145)	0.361** (0.089)
$corr\left(\hat{\sigma}_t^{\pi}, \hat{\pi}_t\right)$	0.113	0.100	0.061	0.513	0.510	0.424

Notes: Estimation period is 1923-2013. $\overline{\pi}_t$ is average inflation, $\overline{\pi}_t^{HP}$ is the HP trend inflation, and σ_t^{π} is inflation volatility. See text for variable definitions. The Japanese sample excludes observations with inflation values exceeding 30%. Estimated standard errors in parentheses. '**' and '*' denote statistical significance at the 1% and 5% significance levels.

substantially larger (and statistically significant) for Japan. In particular, the estimated βs range from 0.03 to 0.05 in the US, and from 0.36 to 0.75 in Japan. Similarly, the estimated correlations are all positive, ranging from 0.06 to 0.11 in the US, and from 0.42 to 0.51 in Japan. These relationships are visualized in the scatterplots of Figure 4 for the US, and Figure 5 for Japan, showing the overall positive correlation between inflation volatility on the one hand, and average inflation or trend inflation on the other.

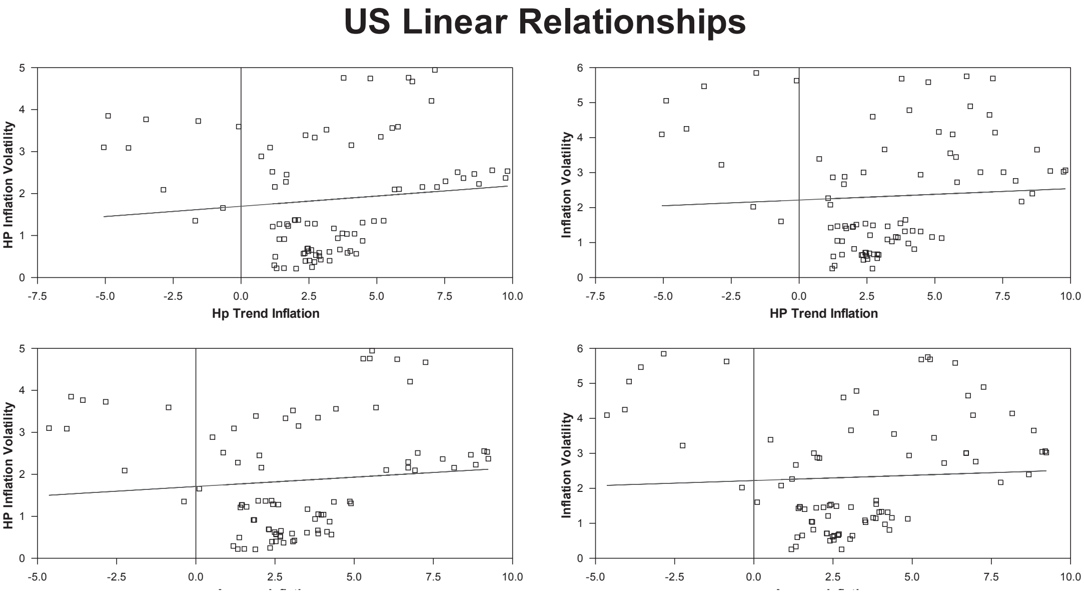

Figure 4.

Inflation Volatility versus HP Trend Inflation, and Average Inflation

Notes: Scatter plots include annual observations over the period 1923-2013. Straight lines are regression lines.

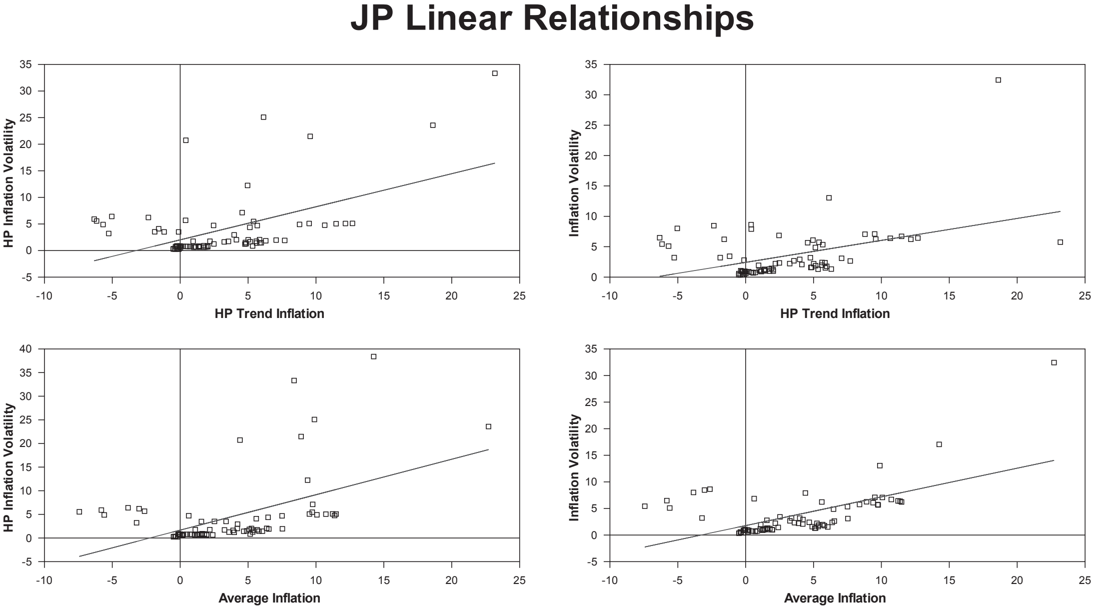

Figure 5.

Inflation Volatility versus HP Trend Inflation, and Average Inflation

Notes: Scatter plots include annual observations over the period 1923-2013. Straight lines are regression lines.

3.2. Break at 3.5%?

Next, we test the CGW (2012) hypothesis that:

> "[at] low levels of inflation, increasing $\overline{\pi}$ reduces the volatility of inflation [...]. When $\overline{\pi}$ rises past a specific value [...] the variance of inflation rises with $\overline{\pi}$. Given our baseline values, this switch occurs at an annualized trend inflation rate of approximately 3.5%." (Coibion, Gorodnichenko, and Wieland, 2012).

To test that there is a break in the relationship which is located at 3.5% annual inflation, the estimated model becomes:

$$\hat{\sigma}_t^{\pi} = \alpha + \beta_{LOW}\hat{\pi}_t\mathbf{I}(\overline{\pi}_t \le 3.5) + \beta_{HIGH}\hat{\pi}_t\mathbf{I}(\overline{\pi}_t > 3.5) + u_t, \qquad (2)$$

where $\mathbf{I}(\cdot)$ is the indicator function, and again $\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$ or σ_t^{HP}; and $\hat{\pi}_t = \overline{\pi}_t$, or $\overline{\pi}_t^{HP}$. In effect, model (2) estimates two linear relationships: one for inflation values that fall short of 3.5% (captured by β_{LOW}), and another for inflation values that exceed 3.5% (captured by β_{HIGH}).

The results of this split estimation are given in Table 2. The picture now changes dramatically for both countries. The estimated β_{LOW} s range from –0.3 to –0.5 in the US, and from –0.49 to –0.52 in Japan; while the estimated β_{HIGH} s vary from 0.2 to 0.3 in the US, and from 0.7 to 1.4 in Japan. In addition to being considerably greater in magnitude, these coefficients are also more statistically significant than those of Table 1. Note that the estimated β_{LOW} s are all negative, while the estimated β_{HIGH} s are all positive, so the evidence appears to be strongly supportive of the CGW hypothesis. It appears that, in both Japan and the US, the relationship between inflation and inflation volatility is positive for (trend) inflation higher than 3.5%, but it becomes negative for (trend) inflation below 3.5%.

Table 2

Break at 3.5% Inflation

$$\hat{\sigma}_t^{\pi} = \alpha + \beta_{LOW}\hat{\pi}_t\mathbf{I}(\bar{\pi}_t \leq 3.5) + \beta_{HIGH}\hat{\pi}_t\mathbf{I}(\bar{\pi}_t > 3.5) + u_t$$

	US			JAPAN		
	$\hat{\sigma}_t^{\pi} = \sigma_t^{HP}$		$\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$	$\hat{\sigma}_t^{\pi} = \sigma_t^{HP}$		$\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$
	$\hat{\pi}_t = \bar{\pi}_t^{HP}$	$\hat{\pi}_t = \bar{\pi}_t$	$\hat{\pi}_t = \bar{\pi}_t^{HP}$	$\hat{\pi}_t = \bar{\pi}_t^{HP}$	$\hat{\pi}_t = \bar{\pi}_t$	$\hat{\pi}_t = \bar{\pi}_t^{HP}$
β_{LOW}	–0.331**	–0.348**	–0.488**	–0.492*	–0.515**	–0.516**
	(0.064)	(0.069)	(0.077)	(0.212)	(0.099)	(0.145)
β_{HIGH}	0.224	0.297*	0.220	1.300**	1.433**	0.753**
	(0.120)	(0.119)	(0.014)	(0.246)	(0.367)	(0.194)
$corr(\hat{\sigma}_t^{\pi}, \hat{\pi}_t \| \bar{\pi}_t \leq 3.5)$	–0.595	–0.588	–0.670	–0.335	–0.634	–0.476
$corr(\hat{\sigma}_t^{\pi}, \hat{\pi}_t \| \bar{\pi}_t > 3.5)$	0.314	0.399	0.273	0.695	0.556	0.577

Notes: Estimation period is 1923-2013. $\bar{\pi}_t$ is average inflation, $\bar{\pi}_t^{HP}$ is the HP trend inflation, and σ_t^{π} is inflation volatility. See text for variable definitions. The Japanese sample excludes observations with inflation values exceeding 30%. Estimated standard errors in parentheses. '**' and '*' denote statistical significance at the 1% and 5% significance levels.

Figures 6 and 7, for the US and Japan respectively, visualize the implied nonlinear relationships when the break point is assumed to be at 3.5% trend (or average) inflation. The conditional correlation coefficients reported at the bottom of Table 2 make the same point: inflation

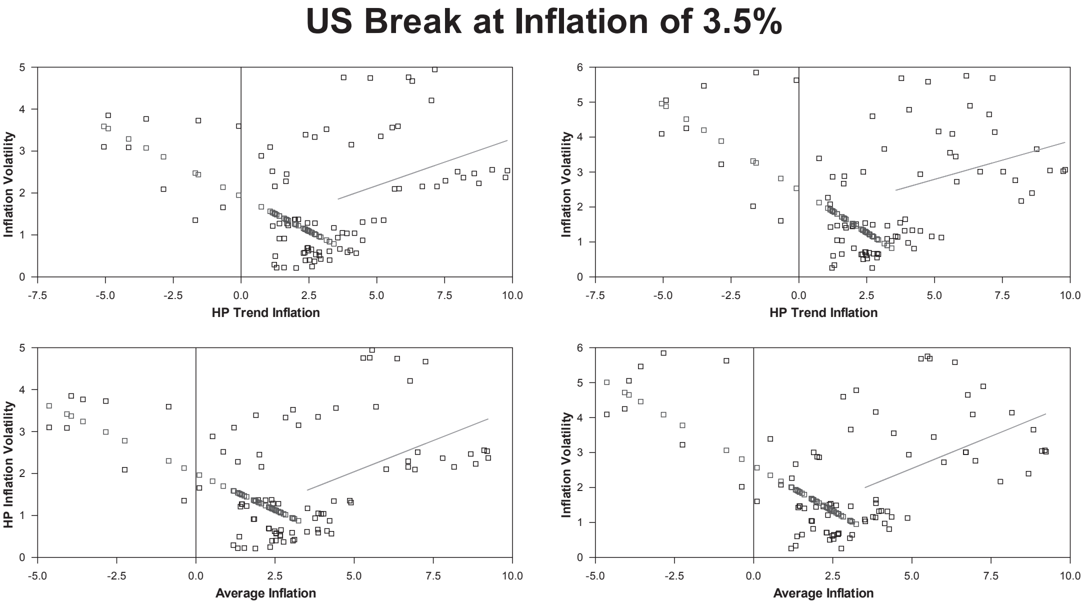

Figure 6.

Inflation Volatility versus HP Trend Inflation, and Average Inflation—Assuming a break at 3.5% Inflation

Notes: Straight lines are regression lines assuming a break at 3.5% inflation.

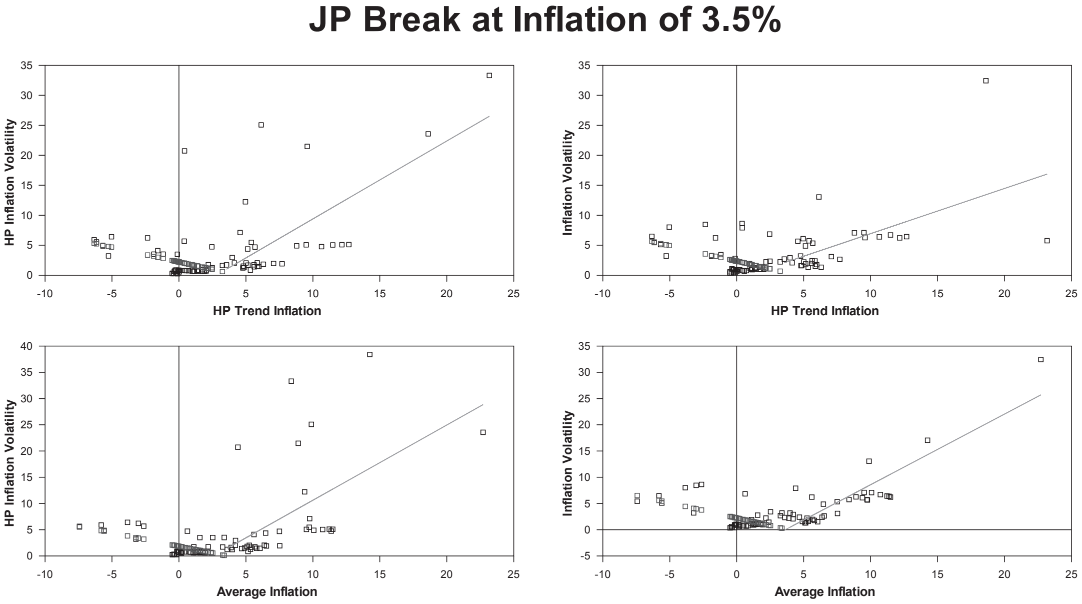

Figure 7.

Inflation Volatility versus HP Trend Inflation, and Average Inflation—Assuming a break at 3.5% Inflation

Notes: Straight lines are regression lines assuming a break at 3.5% inflation.

and its volatility are positively correlated when inflation is above 3.5%, but negatively correlated when inflation falls below 3.5%. Note again that allowing for the break at 3.5% strengthens the estimated correlations between inflation volatility and trend (or average) inflation. It appears that the low correlation coefficients we obtained in section 3.1 above for the full samples are a consequence of not allowing for the non-linearity. In particular, when trend inflation is below 3.5%, its correlation with inflation volatility is around –0.6 in the US and between –0.3 and –0.7 in Japan. On the other hand, when trend inflation exceeds 3.5%, its correlation with inflation volatility is between 0.3 and 0.4 in the US and between 0.6 and 0.7 in Japan.

3.3. Estimating the break

In the last section, we investigated the possibility of a nonlinear relationship, under the assumption that the break occurs at trend (or average) inflation of 3.5%, as suggested by the theory of Coibion, Gorodnichenko, and Wieland (2012). In this section, the goal is to let the data identify the break. To allow for a nonlinear relationship between inflation volatility and (trend) inflation, we estimate a simple quadratic model:

$$\hat{\sigma}_t^{\pi} = \alpha + \beta\hat{\pi}_t + \gamma\left(\hat{\pi}_t\right)^2 + u_t\,, \qquad (3)$$

where once more $\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$ or σ_t^{HP}; and $\hat{\pi}_t = \overline{\pi}_t$, or $\overline{\pi}_t^{HP}$.

The results are reported in Table 3 and the evidence is again supportive of a nonlinear relationship between trend inflation and inflation volatility. The estimated βs are strongly statistically significant for the US, ranging from –0.17 to –0.35; while they are less precisely estimated for Japan, ranging between 0 and –0.24. The estimated γs, however, are highly statistically significant in both economies, varying from 0.04 to 0.07 in the US, and from 0.03 to 0.07 in Japan. We note that the estimated βs are all negative, while the estimated γs are all

Table 3

Quadratic Relationship

$$\hat{\sigma}_t^{\pi} = \alpha + \beta\hat{\pi}_t + \gamma(\hat{\pi}_t)^2 + u_t$$

	US			JAPAN		
	$\hat{\sigma}_t^{\pi} = \sigma_t^{HP}$		$\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$	$\hat{\sigma}_t^{\pi} = \sigma_t^{HP}$		$\hat{\sigma}_t^{\pi} = \sigma_t^{\pi}$
	$\hat{\pi}_t = \bar{\pi}_t^{HP}$	$\hat{\pi}_t = \bar{\pi}_t$	$\hat{\pi}_t = \bar{\pi}_t^{HP}$	$\hat{\pi}_t = \bar{\pi}_t^{HP}$	$\hat{\pi}_t = \bar{\pi}_t$	$\hat{\pi}_t = \bar{\pi}_t^{HP}$
β	–0.174**	–0.217**	–0.345**	–0.140	–0.031	–0.244**
	(0.065)	(0.068)	(0.080)	(0.160)	(0.133)	(0.072)
γ	0.039**	0.046**	0.066**	0.063**	0.033**	0.072**
	(0.009)	(0.009)	(0.011)	(0.010)	(0.009)	(0.005)
Vertex	2.206**	2.371**	2.630**	1.108	0.476	1.692**
	(0.554)	(0.481)	(0.388)	(1.124)	(1.940)	(0.410)

Notes: Estimation period is 1923-2013. $\bar{\pi}_t$ is average inflation, $\bar{\pi}_t^{HP}$ is the HP trend inflation, and σ_t^{π} is inflation volatility. See text for variable definitions. The Japanese sample excludes observations with inflation values exceeding 30%. Estimated standard errors in parentheses. '**' and '*' denote statistical significance at the 1% and 5% significance levels.

positive, suggesting that the nonlinear relationship between inflation volatility and trend (or average) inflation is captured by a convex parabola, consistent with the nonlinearity implied by Coibion, Gorodnichenko, and Wieland (2012).

Figures 8 (for the US) and 9 (for Japan) plot some of the estimated parabolas, clearly showing that the vertex occurs at positive, though relatively low, inflation values. The last couple of rows

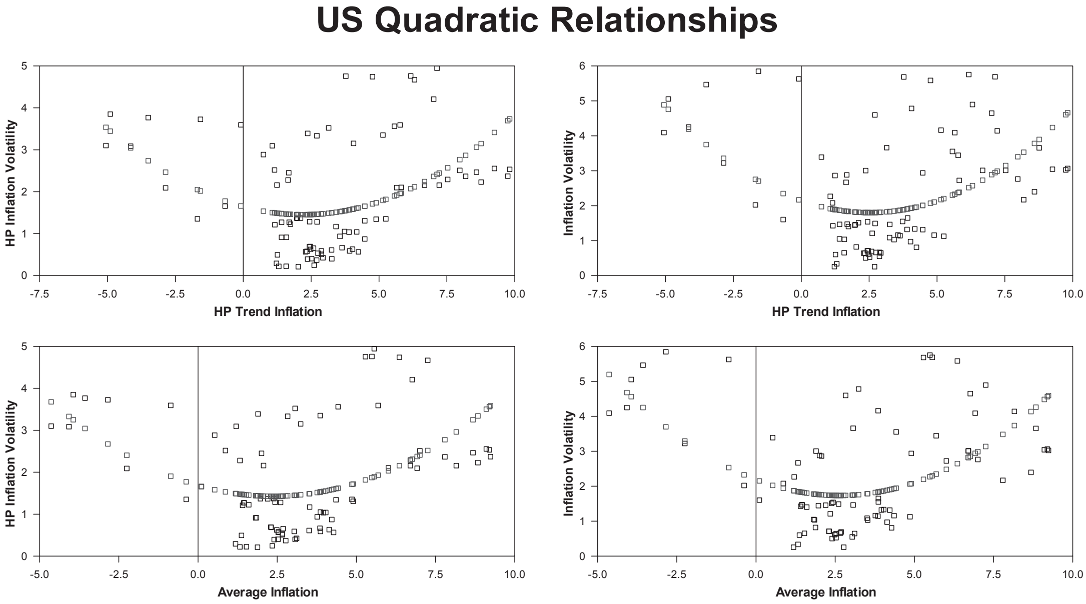

Figure 8.

Inflation Volatility versus HP Trend Inflation, and Average Inflation – Assuming a Quadratic Relationship

Note: Parabolas plot fitted values from the quadratic regressions.

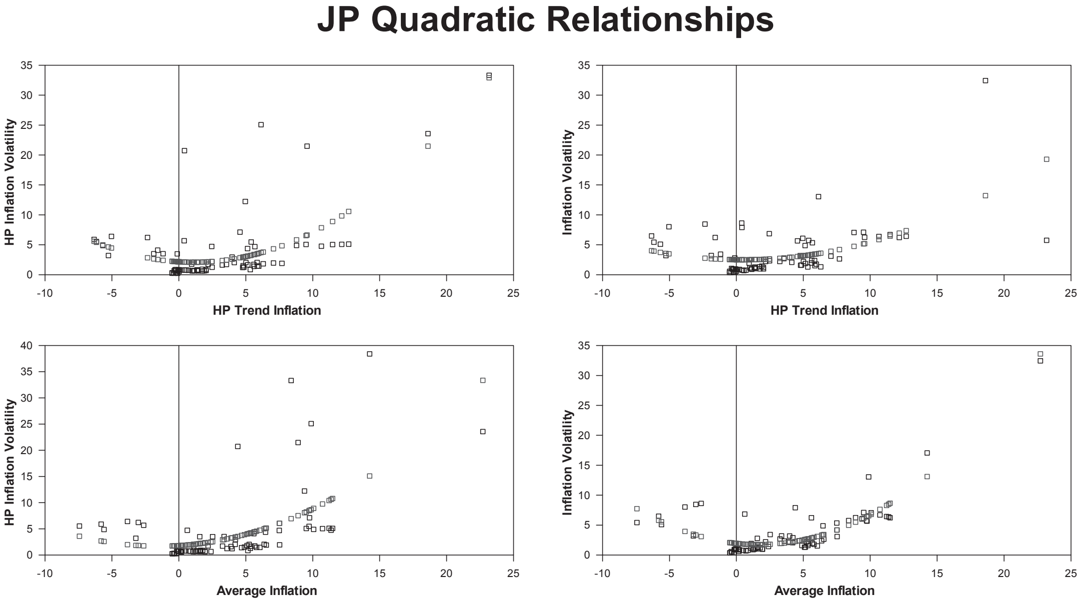

Figure 9.

Inflation Volatility versus HP Trend Inflation, and Average Inflation – Assuming a Quadratic Relationship

Note: Parabolas plot fitted values from the quadratic regressions.

of Table 3 estimate these vertices and their standard errors, using the Delta method. It appears that the trend (or average) inflation rate that minimizes inflation volatility is around 2.5% for the US, and ranges from 0.5% to 1.7% in Japan. We note that these point estimates for the break point are lower than the 3.5% annual inflation rate value predicted by Coibion, Gorodnichenko, and Wieland (2012) and are in fact closer to the 2% inflation target used by many central banks (see Ball, 2013).[7]

4. Discussion and Conclusions

This paper investigated the relationship between inflation and inflation volatility. Using annual Japanese and US data from 1922 to 2013, the results show that the relationship between inflation and its volatility is not monotonic. In particular, the evidence suggests that inflation and its volatility in both countries have been positively correlated when inflation exceeded a certain value, but negatively correlated when inflation was below this threshold. These results are found to be robust to a number of different empirical specifications and estimation techniques.

What is the inflation rate that minimizes inflation volatility? Our evidence suggests that the break in the US occurs around an annual inflation rate of 2.5%. In Japan, the break is estimated at an inflation rate between 0% and 2%. These values are closer to the 2% (formal or informal) inflation target of many central banks, than the 3.5% break point predicted by the New Keynesian model of Coibion, Gorodnichenko, and Wieland (2012).

The significance of the paper's results is straightforward. Most importantly, the evidence

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[7] The distinction between the Japanese and US volatility-minimizing inflation rates becomes less sharp if the estimated standard errors are considered. Using the HP values from Table3, for example, 95% confidence intervals for these minima are (1.1 , 3.3) for the US, and (-1.1 , 3.3) for Japan.

Appendix: Unit Root Tests

A. CPI Price Levels (P_t)

	US			JAPAN		
	PP		DF	PP		DF
	LAGS = 1	LAGS = 4	LAGS = 1	LAGS = 1	LAGS = 4	LAGS = 1
T-stat	–0.609	–0.564	–1.017	–1.473	–1.673	–1.911

B. Inflation Rates (π_t)

	US			JAPAN		
	PP		DF	PP		DF
	LAGS = 1	LAGS = 4	LAGS = 1	LAGS = 1	LAGS = 4	LAGS = 1
T-stat	–4.105**	–3.529**	–4.860**	–6.884**	–6.967**	–5.010**

Notes: PP refers to the Phillips-Perron (1988) tests; DF to the Dickey-Fuller (1979) tests. A deterministic time trend has been included in the CPI Price level models. '**' and '*' denote statistical significance at the 1% and 5% significance levels.

shows that, contrary to a broad consensus, lower inflation has not always been more stable inflation. The implication is that, if inflation falls below the break point, raising it may result in lower instead of higher inflation volatility. Does this strengthen the argument of those who call for higher inflation targets (such as such as Blanchard, Dell'Ariccia, and Mauro, 2010; Ball, 2013)? In practice, this depends on the actual value of the threshold. Our estimates imply that raising inflation rates above 2% in Japan or 2.5% in the US is likely to result in higher inflation volatility.

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