The Nonlinear Relationship between Inflation and Inflation Uncertainty: Evidence of the East Asian Countries

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Abstract

We revisit the relationship between inflation and inflation uncertainty by a nonlinear flexible regression model of four economies in East Asia, that is, Taiwan, Hong Kong, Singapore, and South Korea. Two hypothesis will be examined. One hypothesis is proposed by Friedman (1977). He argued that increased inflation could raise inflation uncertainty. The other hypothesis is provided by Cukierman and Meltzer (1986), they argued that high level of inflation uncertainty will cause higher rate of inflation. We find overwhelming statistical evidences in favor of Friedman's hypothesis except for Hong Kong. The nonlinearity displays a U shape pattern, implying that high rate of inflation or deflation will cause high inflation uncertainty. On the other hand, Cukierman-Meltzer's hypothesis is also evidenced for all four economies. Hong Kong, Singapore, and South Korea have a positive relation in favor of Cukierman-Meltzer's hypothesis, while Taiwan has a inverted-U shape.

Key Words: Inflation, Inflation Uncertainty, Nonlinear, Flexible Regression Model
JEL Classification: C22, E31

1 Introduction

Inflation is always an important issue in economics. Many economists try to explore what inflation matters. A well-known Philips curve explains the negative relationship between inflation and economic output.

Okun (1971) was the first one to argue that inflation is positively associated with inflation uncertainty. He found that countries experience higher inflation rate will have larger standard deviation of inflation. Friedman (1977) also argued that, in his Nobel address, higher rate of inflation invokes higher inflation uncertainty. High inflation uncertainty will reduce economic efficiency via the distortion of price signal, such distortions may exert negative impacts on the efficiency of resource allocation and the level of real economic activity. Ball (1992) formalized Friedman's hypothesis and provided a theoretical foundation for the positive relationship between inflation and inflation uncertainty. In his model, there are two type of policymakers who stochastically alternate in power, and the public knows that only one type is willing to bear the economic costs of disinflation. During periods of low inflation, the monetary authorities are willing to keep it low to lower inflation uncertainty. On the contrary, during periods of high inflation, the public does not know for how long it will last before an anti-inflation policy makers come in power.

On the other hand, Cukierman and Meltzer (1986) claimed a reverse direction which is contrast to Friedman's hypothesis that higher inflation uncertainty will raise the rate of inflation. In their model, in the absence of a commitment mechanism, the monetary authorities may engage in discretionary policy. Therefore, the public becomes uncertain about the monetary policy, there is an incentive for the central bankers to act *opportunistically* in terms of seeking to attain higher short-term economic growth. Therefore higher inflation uncertainty will raise average inflation rate. On the contrary, Holland (1995) argued that, under assumptions of Friedman's hypothesis hold and negative effect of inflation uncertainty on growth, the monetary authorities have a motive to *stabilize* inflation when uncertainty rises.

Many empirical studies provide mixing conclusions about this issue. For example, Grier and Perry (1998) investigated the linkage between inflation and inflation uncertainty in the G7 countries. They provided evidences in favor of Friedman's hypothesis for all G7 countries. On the other hand, Japan and France are in favor of Cukierman-Meltzer's hypothesis, while for the U.S., UK and Germany, Holland's hypothesis is accepted. Tevfik and Perry (2000) also found strong evidences in favor of Friedman's hypothesis for Turkey. But the evidence of Cukierman and Meltzer's hypothesis is mixed. Fountas (2001) used a long series of UK inflation data and provided strong evidence in favor of the hypothesis that inflationary periods are associated with high inflation uncertainty, and also indicated that more inflation uncertainty leads to lower output.[1]

In spite of aboundant literature on the inflation and inflation uncertainty, most of them are based on the GARCH-type model and a shortcoming of this model is that it extracts only *linear* relationship between inflation and inflation uncertainty. It overlook the *nonlinear* relationship if it really exit in the data. We have no reasons to exclude, whatsoever, other possible functional forms for describing such a relation. In this study, we revisit Friedman's and Cukierman and Meltzer's hypotheses in terms of Hamilton (2001) flexible regression model. The merit of this approach is that we can simultaneously detect linear and nonlinear relationships of the data.

Within the flexible nonlinear inference, the nonlinear tests are based on the Largrange-multiplier test. The null hypothesis is absence of nonlinearity, while the alternative hypothesis allows for a broad class of deterministic nonlinear function. Following Hamilton (2001), Dahl and Gonzále-Rivera (2003) also developed various nonlinear test statistic.

We use monthly data of the consumer price index (CPI) of four East Asian economies, that is, Taiwan, Hong Kong, Singapore, and South Korea. In our empirical results, we find that Taiwan, Singapore, and South Korea are in favor of Friedman's hypothesis while Kong Kong fails to support it. In details, the patterns of the effect of inflation on inflation uncertainty show the U shape in these three economies. The nonlinear patterns suggest that inflation uncer-

[1]Readers are referred to, for instance, Engle (1982), Bollerslev (1986), Ball and Cecchetti (1990), Cosimano and Jansen (1988) and Baillie et al. (1996) for more empirical evidences on these hypotheses.

tainty appear to increase in inflationary and deflationary period.

Moreover, these four economies all accept Cukierman-Meltzer's hypothesis, implying that high level of inflation uncertainty will raise higher rate of inflation. Hong Kong, Singapore, and South Korea show a absolutely positive and nonlinear relation in favor of Cukierman-Meltzer's hypothesis. The results imply that the central banker of these countries are intended to behave opportunistic policies to create inflation surprises to rise economic output. Interestingly, Taiwan has inverted-U shape relation on the effect of inflation uncertainty on inflation. It implies that the monetary authorities only act opportunistic policy under a specific level of inflation uncertainty.

The outline of the paper is as follows. In section 2, we will review the flexible regression model and nonlinear test proposed by Hamilton (2001) and Dahl and Gonzále-Rivera (2003). Section 3 presents our empirical results of four Asian economies. Conclusions are offered in Section 4.

2 Flexible Regression Model

Hamilton (2001) proposed a new approach, flexible regression model, to detect the nonlinearity of the data. He employed the concept of random field to describe the nonlinear component of the model. The model is as follows:

$$y_t = \mu(\boldsymbol{x}_t) + \varepsilon_t, \tag{1}$$

where

$$\mu(\boldsymbol{x}_t) = \alpha_0 + \boldsymbol{\alpha}'\boldsymbol{x}_t + \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_t), \tag{2}$$

where y_t and $\boldsymbol{x}_t$ are stationary and ergodic process. In this model, the symbol $\odot$ denotes the element-by-element multiplication, and $m(\cdot)$ is the outcome of random field. From the model (1), it contains the linear component $\alpha_0 + \boldsymbol{\alpha}'\boldsymbol{x}_t$ and the nonlinear component $\lambda m(\boldsymbol{g} \odot \boldsymbol{x}_t)$, where $m(\cdot)$ is latent and unseen. Term λ makes a contribution to the nonlinearity and $\boldsymbol{g}$ controls the curvature.

Furthermore, for any choice of $\boldsymbol{x}$, $m(\boldsymbol{x})$ is a realization from a random field and is distributed in

$$m(\boldsymbol{x}) \sim \mathcal{N}(0,1),$$
$$\mathrm{E}[m(\boldsymbol{x})m(\boldsymbol{z})] = H_k(h),$$

for

$$H_k(h) = \begin{cases} G_{k-1}(h,1)/G_{k-1}(0,1) & \text{if } h \leqslant 1, \\ 0 & \text{if } h > 1, \end{cases}$$

where

$$G_k(h,r) = \int_h^r (r^2 - z^2)^{k/2}\, dz$$

for $h \equiv (1/2)[(\boldsymbol{x}-\boldsymbol{z})'(\boldsymbol{x}-\boldsymbol{z})]^{1/2}$ based on Euclidean distance.

2.1 Estimation

We can not infer the conditional expectation function $\mu(\boldsymbol{x}_t)$ and parameters $\vartheta = (\alpha, \boldsymbol{\alpha}', \sigma, \boldsymbol{g}', \lambda)'$ since the $m(\cdot)$ is unseen and latent. Hamilton proposed to represent equation (1) and (2) as GLS form to divide the unobserved part $m(\boldsymbol{x})$ into the residual. He rephrases the model as

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_t \end{bmatrix} = \begin{bmatrix} 1 & \boldsymbol{x}_1' \\ 1 & \boldsymbol{x}_2' \\ \vdots & \vdots \\ 1 & \boldsymbol{x}_T' \end{bmatrix} \begin{bmatrix} \alpha_0 & \boldsymbol{\alpha}' \end{bmatrix} + \begin{bmatrix} \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_1) + \varepsilon_1 \\ \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_2) + \varepsilon_2 \\ \vdots \\ \lambda m(\boldsymbol{g} \odot \boldsymbol{x}_T) + \varepsilon_T \end{bmatrix},$$

or

$$\boldsymbol{y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{u}.$$

Then, he suggested the maximum likelihood estimate (MLE) with recursive formulation, like the Kalman filter, to obtain the parameters ϑ. Conditional on an initial set of parameters $\lambda, \boldsymbol{g}$ and by defineing $\zeta = \lambda/\sigma$ and $\boldsymbol{W}(\boldsymbol{X};\boldsymbol{\theta}) = \zeta^2 \boldsymbol{H}(\boldsymbol{g}) + \boldsymbol{I}_T$, the parameters of the linear part, i.e., β and σ^2, can be calculated analytically as

$$\tilde{\boldsymbol{\beta}}(\boldsymbol{\theta}) = [\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{X};\boldsymbol{\theta})^{-1}\boldsymbol{X}]^{-1}[\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{X};\boldsymbol{\theta})^{-1}\boldsymbol{y}], \tag{3}$$
$$\tilde{\sigma}^2(\boldsymbol{\theta}) = [\boldsymbol{y} - \boldsymbol{X}\tilde{\boldsymbol{\beta}}(\boldsymbol{\theta})]'\boldsymbol{W}(\boldsymbol{X};\boldsymbol{\theta})^{-1}[\boldsymbol{y} - \boldsymbol{X}\tilde{\boldsymbol{\beta}}(\boldsymbol{\theta})]/T, \tag{4}$$

where $\boldsymbol{I}_T$ denotes an $T \times T$ identity matrix and $\boldsymbol{\theta} = (\boldsymbol{g}', \zeta)'$. Thus, we can write the concentrated log likelihood function as

$$\eta(\boldsymbol{\theta}; \boldsymbol{y}, \boldsymbol{X}) = -\frac{T}{2}\ln(2\pi) - \frac{T}{2}\ln\tilde{\sigma}^2(\boldsymbol{\theta}) - \frac{1}{2}\ln|\boldsymbol{W}(\boldsymbol{X}; \boldsymbol{\theta})| - \frac{T}{2} \tag{5}$$

and then to obtain $\{\hat{\alpha}, \hat{\boldsymbol{\alpha}}', \hat{\sigma}^2, \hat{\boldsymbol{g}}', \hat{\zeta}'\}$ by maximizing equation (5).

2.2 Nonlinearity Test

In the framework of equation (1) and (2), it is easy to observe that we can test the linearity either by λ or by vector $\boldsymbol{g}$ which makes contribution to the nonlinearity and curvature, respectively. If the null hypothesis $H_0 : \lambda^2 = 0$ is rejected, implying that the nonlinear component $\lambda m(\boldsymbol{g} \odot \boldsymbol{x}_t)$ in equation (2) disappears. On the other hand, if the null hypothesis $H_0 : \boldsymbol{g} = \boldsymbol{0}_k$ is rejected, suggesting that the individual variable contribute no nonlinear properties to the model. Hamilton (2001) proposed a λ-test, called $\lambda_{\text{H}}^{\text{E}}(\boldsymbol{g})$, which is based on Euclidean distance and Hessian type information matrix. The LM statistic for the nonlinearity test can be calculated as

$$\lambda_{\text{H}}^{\text{E}}(\boldsymbol{g}) = \frac{\hat{\boldsymbol{u}}'\boldsymbol{H}_T\hat{\boldsymbol{u}} - \tilde{\sigma}_T^2\text{tr}(\boldsymbol{M}_T\boldsymbol{H}_T\boldsymbol{M}_T)}{\left(2\text{tr}\left\{[\boldsymbol{M}_T\boldsymbol{H}_T\boldsymbol{M}_T - (T-k-1)^{-1}\boldsymbol{M}_T\text{tr}(\boldsymbol{M}_T\boldsymbol{H}_T\boldsymbol{M}_T)]^2\right\}\right)^{1/2}} \sim \chi^2(1), \tag{6}$$

where $\boldsymbol{M} = \boldsymbol{I}_T - \boldsymbol{X}(\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{X}'$.

Furthermore, Dahl and Gonzále-Rivera (2003) propose alternative two λ-tests to circumvent the nuisance problem of $\boldsymbol{g}$. They are $\lambda_{\text{OP}}^{\text{E}}$ and $\lambda_{\text{OP}}^{\text{A}}$ based on Minkowski distance. The former is based on known covariance functions and can be calculated as

$$\lambda_{\text{OP}}^{\text{E}}(\boldsymbol{g}) = \frac{T^2}{2}\frac{\boldsymbol{\kappa}'\tilde{\boldsymbol{x}}(\tilde{\boldsymbol{x}}'\tilde{\boldsymbol{x}})\tilde{\boldsymbol{x}}\boldsymbol{\kappa}}{\boldsymbol{\kappa}'\boldsymbol{\kappa}} \sim \chi^2(1). \tag{7}$$

The latter is based on unknown covariance functions, and can be written as

$$\lambda_{\text{OP}}^{\text{A}} = T^2R^2 \sim \chi^2(q^*)$$

where $q^* = 1 + \sum_{j=1}^{2k+2}\binom{k+j-1}{k-1}$.

Moreover, Dahl and Gonzále-Rivera (2003) also provides g-test, denoted as g_{OP}, which is based on Minkowski distance and also is free of nuisance problem of λ parameter under the null. The LM statistic can be expressed as

$$g_{\text{OP}} = T^2R^2 \sim \chi^2(k). \tag{8}$$

3 Empirical Study

3.1 Data Description and Uncertainty Measurement

We use monthly data of consumer price index of the Four Dragon of East Asia, that is, Taiwan, Hong Kong, Singapore, and South Korea, to investigate the relationships between inflation and inflation uncertainty. The sample period are 1980:01∼2002:12, 1985:01∼2003:07, 1977:01∼2003:07, and 1965:01∼2003:08 for Taiwan, Hong Kong, Singapore, and South Korea, respectively. The data sources come from Taiwan Education AREMOS Data Bank.

Preliminarily we need to solve a problem that how to measure the inflation uncertainty? The traditional approach to investigate this issue is by the GARCH-type models. The merit of this model is that the inflation uncertainty is automatic constructed by the conditional heteroscedasticity estimate of the GARCH model. Because the flexible regression model cannot generate the conditional variance as the GARCH model, we need to construct a specific measure for the inflation uncertainty.[2] Following Arize et al. (2000), we instead take the measurement of moving average standard deviation as our proxy for the inflation uncertainty. The inflation uncertainty measurement is defined as follows

$$J_{t+m} = \left[\frac{1}{m}\sum_{i=1}^{m}(R_{t+i-1} - R_{t+i-2})^2\right]^{1/2}, \tag{9}$$

[2]A fundamental problem of this measurement is that it is a "generated regressor variable" which might understate the true inflation uncertainty. However, Lo and Piger (2003) presents the estimating results between generated and ungenerated variables and find little difference between them. Hamilton's approach is a trad-off because GARCH model cannot catch the nonlinear relationships between inflation rate and inflation uncertainty, though, it avoids the generated regressor problem inherently.

where R is the nature logarithm of CPI, and m is the order of the moving average. In this study, we employ the order $m = 7$.

3.2 Econometric Model

We employ Hamilton's flexible regression model to find the relationships between inflation rate and inflation uncertainty. We focus on two hypotheses. The first is "Friedman's hypothesis", that is, does higher rate of inflation increase higher inflation uncertainty? Another hypothesis is "Cukierman-Meltzer's hypothesis" which examines does higher inflation uncertainty cause higher level of inflation rate? As discussed in previous section on model's specification, the empirical models for the two hypotheses are as follows

$$\sigma_{\pi_t} = \beta_0 + \sum_{j=1}^{q} \beta_j \sigma_{\pi_{t-j}} + \varphi \pi_t + \lambda_\sigma m(k \odot \boldsymbol{z}_t) + \nu_t, \tag{10}$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \phi \sigma_{\pi_t} + \lambda_\pi m(g \odot \boldsymbol{x}_t) + \varepsilon_t, \tag{11}$$

where $\boldsymbol{z}_t = \{\sigma_{\pi_{t-1}}, \sigma_{\pi_{t-2}}, \ldots, \sigma_{\pi_{t-q}}, \pi_t\}$, $\boldsymbol{x}_t = \{\pi_{t-1}, \pi_{t-2}, \ldots, \pi_{t-p}, \sigma_{\pi_t}\}$. Terms π_t and σ_{π_t} denote the inflation and inflation uncertainty, respectively. Terms q and p denote the optimal lag length of equation (10) and (11), respectively. If the estimate of φ in equation (10) is significantly different from zero, then it provides evidence that the inflation rate have linear effect on the inflation uncertainty. By the same token, if the estimate of ϕ is significantly different from zero, then the inflation uncertainty will exert effect on inflation rate. Instead of linear relation between inflation rate and inflation uncertainty, we catch the nonlinear relationships between them by Hamilton's flexible regression model. We show the detail empirical results in the following paragraphs.

Before estimation, we select the optimal lag lengths of the regressors in equations (10) and (11) by the Schwarz Bayesian criterion (SBC) instead of Akaike information criterion. The reason is based on Dahl and Gonzále-Rivera (2003), they mentioned that "moderate number of lags is recommended to guard against dynamic misspecification." Table 1 reports the results from AR(1) to AR(4). According to parsimonious principle, the final chosen model

Table 1: The results of the optimal lag lengths of regressors selected by SBC

	Taiwan	Hong Kong	Singapore	South Korea
$\sigma_{\pi t-1}$	-12.588	-12.547	-14.540	-12.654
$\sigma_{\pi t-2}$	-12.592^*	-12.556^*	-14.606^*	-12.744^*
$\sigma_{\pi t-3}$	-12.590	-12.539	-14.597	-12.730
$\sigma_{\pi t-4}$	-12.569	-12.514	-14.583	-12.720
π_{t-1}	0.031^*	-0.216	-1.208	0.418
π_{t-2}	0.039	-0.211	-1.306	0.247
π_{t-3}	0.059	-0.391^*	-1.389^*	0.103^*
π_{t-4}	0.057	-0.380	-1.371	0.105

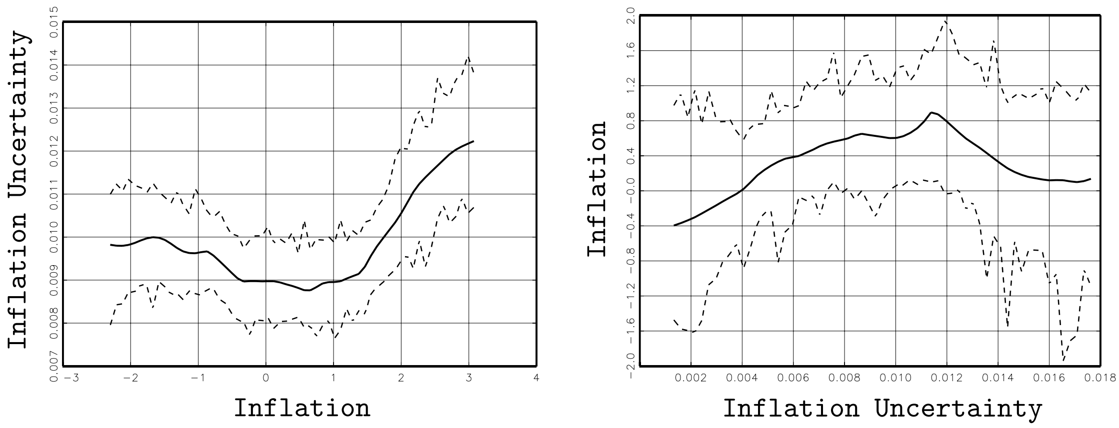
Note: Symbol * denotes the best selection by SBC

is picked up by choosing the minimum value of SBC. For equation (10), the optimal lags are two for all economies. As for equation (11), the optimal lags for Hong Kong, Singapore, and South Korea are three, while for Taiwan it is unity.

3.3 Empirical Analysis

3.3.1 Taiwan

Panel A in Table 2 presents the empirical results of equation (10) i.e., Friedman's hypothesis, and the nonlinear tests statistics. Several observations can be extracted from it. First, if the null hypothesis $\lambda = 0$ is not rejected, then the regression (10) turns out to be linear since the nonlinear part $\lambda_\sigma m(\boldsymbol{k} \odot \boldsymbol{z}_t)$ disappears. From the table, it is clear that the $\lambda^{\mathrm{E}}_{\mathrm{H}}$, $\lambda^{\mathrm{E}}_{\mathrm{OP}}$, and $\lambda^{\mathrm{A}}_{\mathrm{OP}}$ statistics significantly reject the linear null hypothesis in favor of the nonlinear alternative. As a result, we may conclude that the relation is nonlinear. Second, the linear estimate of π_t is not significant at 5% level, it seems that Friedman's hypothesis does not hold for linear relation. Third, as for the nonlinear component, we can observe that the estimates of $\sigma^{\mathrm{TW}}_{\pi_{t-1}}$ and $\sigma^{\mathrm{TW}}_{\pi_{t-2}}$ are insignificantly different from zero, in other words, $\sigma^{\mathrm{TW}}_{\pi_{t-1}}$ and $\sigma^{\mathrm{TW}}_{\pi_{t-2}}$ play no role in the nonlinearity. By contrast, the nonlinear estimate of π^{TW}_t is statistically and significantly different



(a) Friedman's hypothesis (b) Cukierman-Meltzer's hypothesis

Figure 1: The relationship between inflation and inflation uncertainty—Taiwan

from zero, suggesting that the nonlinearity seems to be mainly contributed by the π_t^{TW} variable. The result is evidenced by the linear test g_{OP} is significantly rejected.

As addressed in Hamilton (2001), given values of $\vartheta = \{\beta_0, \beta_1, \beta_2, \varphi, \zeta, k_1, k_2, k_3, \sigma\}$, we can calculate a value for equation (10) for any $\boldsymbol{z}^*$ of interest, which represents the econometrician's inference as the value of the conditional mean $\mu(\boldsymbol{z}^*)$ when the explanatory variables take on the value represented by $\boldsymbol{z}^*$ and when the parameters are known to take on these specified values. Figure 1(a) plots the conditional expectation function with respective to π_t^{TW} holding σ_{t-1}^{TW}, and σ_{t-2}^{TW} constant, i.e., the figure plots $\hat{\text{E}}[\mu(\bar{\sigma}_{t-1}^{\text{TW}}, \bar{\sigma}_{t-2}^{\text{TW}}, \pi_t^{\text{TW}})|\boldsymbol{Y}_T]$ as a function of π_t^{TW} for $\bar{\sigma}_{t-1}^{\text{TW}}$, $\bar{\sigma}_{t-2}^{\text{TW}}$ the sample mean for variable σ_{t-1}^{TW}, σ_{t-2}^{TW}, and $\boldsymbol{Y}_T$ the given sample observations on σ_t^{TW}, σ_{t-1}^{TW}, σ_{t-2}^{TW}, and π_t^{TW}. Solid line is the posterior mean with $N = 5,000$ Monte Carlo draws for specification. Dashed lines are the 95% confidence intervals.

Figure 1(a) displays the U-shaped relation between inflation and inflation uncertainty. It shows that if deflation rate increases ($\pi_t^{\text{TW}} < 0$), then the deflation uncertainty will increase. Likewise, if inflation rate increases ($\pi_t^{\text{TW}} > 0$), then the inflation uncertainty will increase. Furthermore, inflation uncertainty is more sensitive to inflation in inflationary period than that in deflationary period, since the slope is asymmetric. Another interesting observation is that minimum level of inflation is at around 0.8%, suggesting that the best inflation target level to minimize the inflation uncertainty for the monetary authority is to set inflation rate at about 0.8%.

Overall, the linear estimate suggests that higher inflation rate have no effect on inflation uncertainty because φ is not significantly different from zero. However, from the estimate of nonlinear component k_3, the inflation rate exerts significantly and positive effect on inflation uncertainty, suggesting that Friedman's hypothesis is supportable. This result provides evidence that we might make a bias conclusion if we ignore the important nonlinear component of the data.

Panel B of Table 2 summarizes the results of equation (11), which allow us to examine the reverse relationship that does higher inflation uncertainty cause higher rate of inflation (Cukierman-Meltzer's hypothesis)? First note that, again, the linear null hypothesis is significantly rejected by the λ test statistics at the 5% level in favor of nonlinearity. Second, the linear estimate of ϕ is significantly and positively different from zero, suggesting that the inflation uncertainty has linear effect on inflation rate.

If we pay attention to the nonlinear component estimates, then we can find that the estimates of π_{t-1}^{TW} and σ_t^{TW} are significantly different from zeros. The results are consistent with the linear g_{OP} test is rejected in panel B. Furthermore, Figure 1(b) displays an interest pattern (the inverted-U shape) of the effect of σ_t^{TW} on π_t^{TW}, suggesting a nonlinear effect of inflation uncertainty on inflation rate. It is interesting to note that there is a positive relation between inflation uncertainty and inflation rate (Cukierman-Meltzer's hypothesis holds) at a specific level of inflation uncertainty $\sigma_{\pi_t}^{\mathrm{TW}} = 0.012$. When the level of inflation uncertainty is higher than 0.012, the pattern shows a negative relation in favor of Holland's hypothesis. If the level of inflation uncertainty is less than 0.012, then Cukierman and Meltzer's hypothesis is accepted.

3.3.2 Hong Kong

The empirical results of Friedman's hypothesis for Hong Kong are summarized in panel A of Table 3. The linear null hypothesis cannot be rejected by the

Table 2: The estimating results of the linkage between inflation and inflation uncertainty in the case of Taiwan

(A) Friedman's hypothesis: $\sigma_{\pi_t} = \beta_0 + \sum_{j=1}^{q} \beta_j \sigma_{\pi_{t-j}} + \varphi \pi_t + \sigma[\zeta m(\boldsymbol{k} \odot \boldsymbol{z}_t) + \nu_t]$

β_0	β_1	β_2	φ	σ	ζ	k_1	k_2	k_3	$\lambda_{\text{H}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{A}}$	g_{OP}
0.004***	0.825***	−0.030	3.8e−4	0.001***	1.025***	−43.926	11.872	0.539***	0.001***	0.001***	0.001***	0.001***
(0.001)	(0.078)	(0.063)	(2.2e−4)	(7.9e−5)	(0.303)	(26.650)	(22.593)	(0.073)				

(B) Cukierman-Meltzer's hypothesis: $\pi_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \phi \sigma_{\pi_t} + \sigma[\zeta m(\boldsymbol{g} \odot \boldsymbol{x}_t) + \varepsilon_t]$

α_0	α_1	ϕ	σ	ζ	g_1	g_2	$\lambda_{\text{H}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{A}}$	g_{OP}
−0.693	0.019	78.946**	0.860***	−0.921	1.157***	215.451***	0.004***	0.028**	0.002***	0.024**
(0.592)	(0.140)	(39.416)	(0.108)	(0.716)	(0.067)	(16.251)				

Rejection of null hypothesis at 1%, 5%, and 10% level is indicated by ***, **, and *, respectively. The number in parenthesis is the standard error.

Table 3: The estimating results of the linkage between inflation and inflation uncertainty in the case of Hong Kong

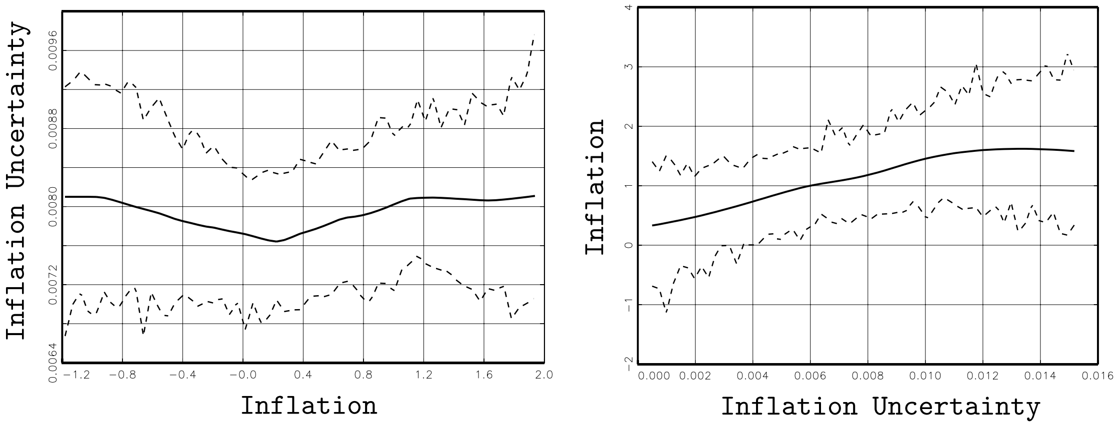
(A) Friedman's hypothesis: $\sigma_{\pi_t} = \beta_0 + \sum_{j=1}^{q} \beta_j \sigma_{\pi_{t-j}} + \varphi \pi_t + \sigma[\zeta m(\boldsymbol{k} \odot \boldsymbol{z}_t) + \nu_t]$

β_0	β_1	β_2	φ	σ	ζ	k_1	k_2	k_3	$\lambda_{\text{H}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{A}}$	g_{OP}
0.001	1.027***	−0.189***	−2.5e−5	0.002***	1.027	97.323	55.030	2.383	0.735	0.672	0.027**	0.132
(4.6e−4)	(0.068)	(0.069)	(1.9e−4)	(9.0e−5)	(0.203)	(245.590)	(456.070)	(2.062)				

(B) Cukierman-Meltzer's hypothesis: $\pi_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \phi \sigma_{\pi_t} + \sigma[\zeta m(\boldsymbol{g} \odot \boldsymbol{x}_t) + \varepsilon_t]$

α_0	α_1	α_2	α_3	ϕ	σ	ζ	g_1	g_2	g_3	g_4	$\lambda_{\text{H}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{E}}$	$\lambda_{\text{OP}}^{\text{A}}$	g_{OP}
−0.266	0.658***	−0.530***	0.433***	38.323	0.539***	1.511***	0.261*	0.591***	0.839***	77.892***	0.005***	0.102	0.001***	0.002***
(0.456)	(0.111)	(0.127)	(0.127)	(32.283)	(0.059)	(0.416)	(0.113)	(0.175)	(0.185)	(28.032)				

Rejection of null hypothesis at 1%, 5%, and 10% level is indicated by ***, **, and *, respectively. The number in parenthesis is the standard error.



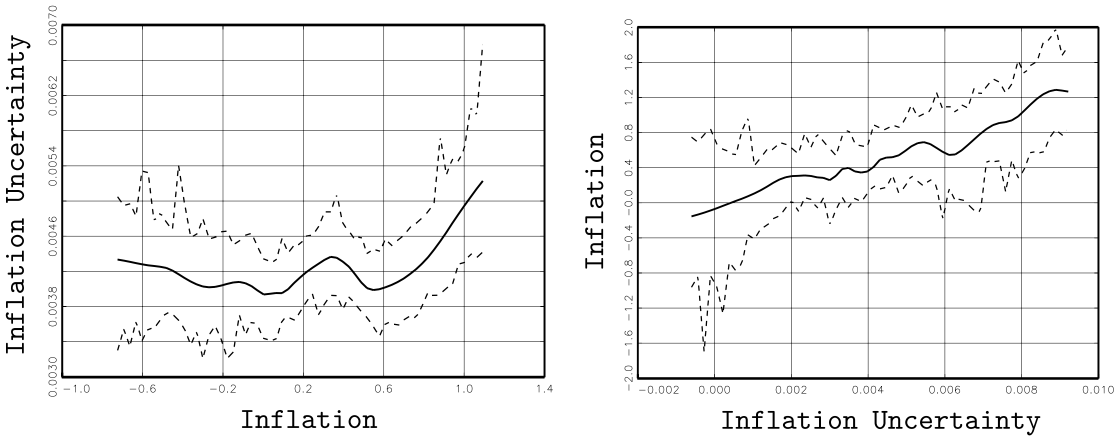
(a) Friedman's hypothesis (b) Cukierman-Meltzer's hypothesis

Figure 2: The relationship between inflation and inflation uncertainty—Hong Kong

$\lambda_{\rm H}^{\rm E}$, $\lambda_{\rm OP}^{\rm E}$, and $g_{\rm OP}$ statistics, but can be rejected by $\lambda_{\rm OP}^{\rm A}$. The conflict consequences induce a difficulty in judging the nonlinear property of the data. For conservative reason, we double check the individual nonlinear component estimates, that is, k_1, k_2, and k_3. The estimates show that they are not significantly different from zero, which is consistent with the linear test result of $g_{\rm OP}$. We conclude that there is no strong nonlinear evidence to support Friedman's hypothesis in Hong Kong. Figure 2(a) graphs the conditional expectation function with respective to $\pi_t^{\rm HK}$. The pattern is relative flat within the interval of 0.0076 and 0.0084, so we think them do not have nonlinear characteristics.

Turn our attention to the Cukierman-Meltzer's hypothesis, empirical results are summarized in the panel B. Two of the linear null hypothesis, λ-test ($\lambda_{\rm H}^{\rm E}$ and $\lambda_{\rm OP}^{\rm A}$) and g-test, are significantly rejected at the 1% level, suggesting that there is nonlinear property in the data. However, the insignificant linear estimate of ϕ provides no evidence that higher inflation uncertainty will exert linear effect on higher inflation rate. Figure 2(b) illustrates us a graphical impression of Cukierman-Meltzer's hypothesis. It displays an absolutely positive impact of inflation uncertainty on inflation rate in favor of Cuikerman-Meltzer's hypothesis.

Overall, Friedman's hypothesis in Hong Kong is not necessarily supportable in our model. By contrast, flexible regression model helps us to find out



(a) Friedman's hypothesis (b) Cukierman-Meltzer's hypothesis

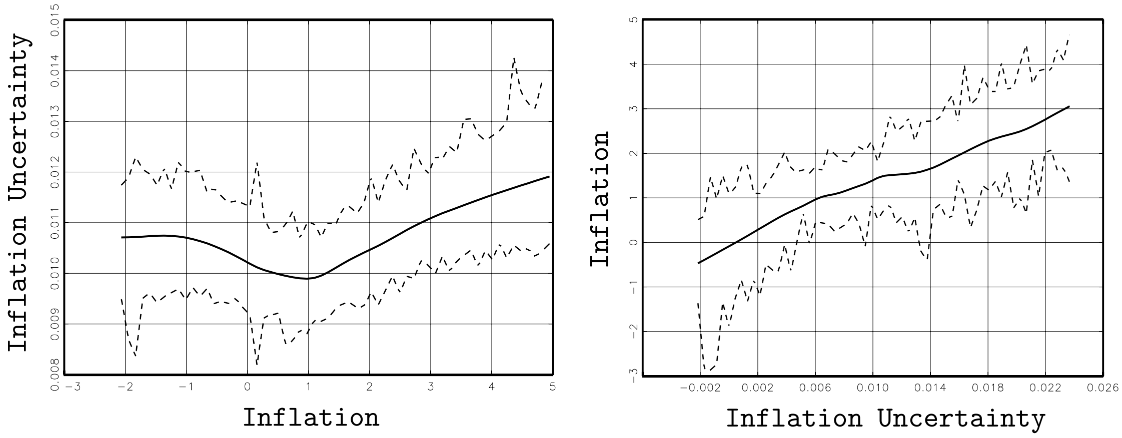
Figure 3: The relationship between inflation and inflation uncertainty—Singapore

the nonlinear property to support Cukierman-Meltzer's hypothesis.

3.3.3 Singapore

Panel A of Table 4 presents empirical results of equation (10) in the case of Singapore. First, the nonlinear test $\lambda_{\mathrm{H}}^{\mathrm{E}}$, $\lambda_{\mathrm{OP}}^{\mathrm{A}}$, and g_{OP} all reject the null hypothesis of the linearity of the model. We conclude that the relationship of equation (10) is nonlinear. Second, the linear estimate of π_t is not significant, implying that Friedman's hypothesis is not supportable. Third, as for the nonlinear component, estimates of $\hat{\boldsymbol{k}} = (413.886, 331.397, 2.245)'$ are statistically significant and different from zeros, indicating that all regressors including inflation π_t have nonlinear and positive effect on inflation uncertainty $\sigma_{\pi t}$. There is a evidence that higher rate of inflation does exert higher inflation uncertainty. Observe Figure 3(a), analogous to Taiwan, the nonlinear pattern is like inverted-U shape, where in inflationary period inflation uncertainty is more sensitive to inflation than that in deflationary period.

Panel B summaries the results for equation (11), i.e., Cukierman-Meltzer's hypothesis. First, nonlinearity tests $\lambda_{\mathrm{H}}^{\mathrm{E}}$, $\lambda_{\mathrm{OP}}^{\mathrm{A}}$, and g_{OP} all reject the null hypothesis of linearity of the model at 1% significant level. It is intended to accept the nonlinear relation in equation (11). Second, the linear estimate of ϕ is significantly different from zero at 10% significant level, suggesting only weaker



(a) Friedman's hypothesis (b) Cukierman-Meltzer's hypothesis

Figure 4: The relationship between inflation and inflation uncertainty—South Korea

linear evidence to support that inflation uncertainty influences rate of inflation.

By contrast, the nonlinear component estimate of σ_t^{SIG} is statistically and significantly different from zero, indicating that high inflation uncertainty has have nonlinear effect on high rate of inflation, i.e., Cukierman-Meltzer's hypothesis is hold. By the same token, Figure 3(b) demonstrates the positive impact of inflation uncertainty on inflation, providing the evidence to support Cukierman-Meltzer's hypothesis.

3.3.4 South Korea

Panel A in Table 5 reports the empirical results of Friedman's hypothesis. A mix result of linearity test is found. The $\lambda_{\text{OP}}^{\text{A}}$ and $\lambda_{\text{E}}^{\text{H}}$ reject linear hypothesis, while the $\lambda_{\text{OP}}^{\text{E}}$ and g_{OP} accept the linear null hypothesis. It becomes difficult for us to judge whether the variables contribute to nonlinearity. However, the nonlinear estimates $\hat{\boldsymbol{k}} = (173.555, 175.302, 0.232)'$ are all significantly different from zero, suggesting that there is the nonlinear properties in the model. As for Friedman's hypothesis, significance of nonlinear estimates of inflation provide the evidence in favor of it even though it is insignificant in linear estimate. Figure 4(a) plots the U shape relation between inflation and inflation uncertainty where the best target inflation rate to minimize inflation uncertainty is about 1%. Park (1995) examines Friedman's hypothesis using South Korea CPI

Table 4: The estimating results of the linkage between inflation and inflation uncertainty in the case of Singapore

(A) Friedman's hypothesis: $\sigma_{\pi_t} = \beta_0 + \sum_{j=1}^{q} \beta_j \sigma_{\pi_{t-j}} + \varphi \pi_t + \sigma[\zeta m(\boldsymbol{k} \odot \boldsymbol{z}_t) + \nu_t]$

β_0	β_1	β_2	φ	σ	ζ	k_1	k_2	k_3	λ_{H}^{E}	λ_{OP}^{E}	λ_{OP}^{A}	g_{OP}
0.001**	1.126***	−0.261***	2.7e−4	5.2e−4***	1.287***	413.886***	331.397**	2.245***	0.036**	0.806	0.025**	0.001***
(4.4e−4)	(0.096)	(0.091)	(2.1e−4)	(3.9e−5)	(0.317)	(121.436)	(132.434)	(0.351)				

(B) Cukierman-Meltzer's hypothesis: $\pi_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \phi \sigma_{\pi_t} + \sigma[\zeta m(\boldsymbol{g} \odot \boldsymbol{x}_t) + \varepsilon_t]$

α_0	α_1	α_2	α_3	ϕ	σ	ζ	g_1	g_2	g_3	g_4	λ_{H}^{E}	λ_{OP}^{E}	λ_{OP}^{A}	g_{OP}
−0.534	0.777***	−0.493***	0.055	126.262*	0.337***	1.861***	0.210***	0.432**	0.091	399.728***	0.002***	0.093*	0.001***	0.001***
(0.533)	(0.113)	(0.163)	(0.077)	(72.703)	(0.034)	(0.668)	(0.092)	(0.162)	(0.064)	(38.033)				

Rejection of null hypothesis at 1%, 5%, and 10% level is indicated by ***, **, and *, respectively. The number in parenthesis is the standard error.

Table 5: The estimating results of the linkage between inflation and inflation uncertainty in the case of South Korea

(A) Friedman's hypothesis: $\sigma_{\pi_t} = \beta_0 + \sum_{j=1}^{q} \beta_j \sigma_{\pi_{t-j}} + \varphi \pi_t + \sigma[\zeta m(\boldsymbol{k} \odot \boldsymbol{z}_t) + \nu_t]$

β_0	β_1	β_2	φ	σ	ζ	k_1	k_2	k_3	λ_{H}^{E}	λ_{OP}^{E}	λ_{OP}^{A}	g_{OP}
0.003***	1.255***	−0.434***	2.6e−4*	0.001***	0.981***	173.555***	175.302***	0.232***	0.041**	0.671	0.019**	0.130
(0.001)	(0.097)	(0.095)	(1.4e−4)	(8.2e−5)	(0.323)	(65.841)	(32.954)	(0.073)				

(B) Cukierman-Meltzer's hypothesis: $\pi_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \phi \sigma_{\pi_t} + \sigma[\zeta m(\boldsymbol{g} \odot \boldsymbol{x}_t) + \varepsilon_t]$

α_0	α_1	α_2	α_3	ϕ	σ	ζ	g_1	g_2	g_3	g_4	λ_{H}^{E}	λ_{OP}^{E}	λ_{OP}^{A}	g_{OP}
−0.828***	0.842***	−0.647***	0.060	155.938***	0.243***	4.153***	0.747***	1.903***	−1.797***	120.757***	0.002***	0.017***	0.001***	0.002***
(0.211)	(0.062)	(0.073)	(0.060)	(16.994)	(0.098)	(1.855)	(0.105)	(0.267)	(0.345)	(26.764)				

Rejection of null hypothesis at 1%, 5%, and 10% level is indicated by ***, **, and *, respectively. The number in parenthesis is the standard error.

Table 6: The summary of empirical results of the relationship between inflation and inflation uncertainty

	Friedman's hypothesis			Cuikerman-Meltzer's hypothesis		
	Linear	Nonlinear	Pattern	Linear	Nonlinear	Pattern
Taiwan	×	○	U	○	○	Inverted-U
Hong Kong	×	×	Flat	×	○	Positive sloped
Singapore	×	○	U	×	○	Positive sloped
South Korea	×	○	U	○	○	Positive sloped

and also find out the U-shaped relation between inflation and inflation uncertainty. He suggests that, under the assumption that inflation uncertainty has a negative effect on real economy, the policymaker should conduct the inflation policy in the range of the threshold level to prevent economic damage from inflation uncertainty

In Panel B, it reports that the linear tests all reject the null hypothesis in favor of nonlinearity alternative. Furthermore, the linear and nonlinear estimates of inflation uncertainty both significantly and positively different from zero, indicating that increased inflation uncertainty raises inflation in favor of Cukierman-Meltzer's hypothesis. Figure 4(b) shows the positive relation about Cukierman-Meltzer's hypothesis, consistent with our empirical results.

3.4 Empirical Illustration and Policy Discussion

Table 6 illustrates a summary of our empirical study. In the linear estimates, Friedman's hypothesis is rejected for these four economies. After applying flexible nonlinear inference, we succeed to capture the nonlinear components to support Friedman's hypothesis except for Hong Kong. Furthermore, the relationships between inflation and inflation uncertainty all show an U shape. It can help the monetary authorities to target an specific level of rate of inflation to minimize inflation uncertainty to prevent economic damage. Another phenomenon from the U-shaped pattern is that the effect of inflation on inflation uncertainty is asymmetric.

On the other hand, by using the nonlinear inference, four economies provide overwhelming evidences in favor of Cuikerman-Meltzer's hypothesis. Three economies (Hong Kong, Singapore, and South Korea) show the positive effect of inflation uncertainty on inflation. Interestingly, Taiwan has a dramatic nonlinear pattern, inverted-U, in describing the relationship between inflation uncertainty and inflation. The effect of inflation uncertainty on inflation is, in general, positive. In details, *under* the specific (threshold) level of inflation uncertainty, the result supports Cuikerman-Meltzer's hypothesis; Instead, *over* the threshold level of inflation uncertainty, Cukierman-Meltzer's hypothesis is not accepted but in favor of Halland's hypothesis. The implications are that the monetary authorities of these three economies (Hong Kong, Singapore, and South Korea) prefer to behave a *opportunistic* policy to rise their economic growth (politically motivated expansionary policy). By contrast, the monetary authorities of Taiwan seem to prefer a discretionary policy. The Taiwan central bank will behave *stabilizing* policy to reduce economic harm when inflation uncertainty exceeds a threshold level.

4 Conclusion

In this paper, we apply Hamilton's (2001) flexible regression model to investigate the relationship between inflation and inflation uncertainty for four economies in the East Asia (Taiwan, Hong Kong, Singapore, and South Korea). Two hypothesis will be examined. One hypothesis is proposed by Friedman (1977), he argued that increased inflation could raise inflation uncertainty. The other hypothesis is provided by Cukierman and Meltzer (1986), they argued that high level of inflation uncertainty will cause higher rate of inflation. We find overwhelming statistical evidences that Friedman's hypothesis is hold except for Hong Kong. Interestingly, the nonlinearities look like U shape, implying that higher rates of inflation and deflation will raise inflation uncertainty. The pattern can help us to find a target rate of inflation to minimize inflation uncertainty and to reduce economic harm.

On the other hand, Cukierman-Meltzer's hypothesis is also evidenced for all four economies. Three economies (Hong Kong, Singapore, and South Korea) display positive relation in favor of Cukierman-Meltzer's hypothesis, while Taiwan has a inverted-U shape. Positive relation of Cukierman-Meltzer's hypothesis indicates that the monetary authorities prefer the *opportunistic* behavior to promote economic growth. On the contrary, in the case of Taiwan, under a specific level of inflation uncertainty, the Taiwan monetary authorities prefer *opportunistic* policy to rise economic growth. However, over a specific level of inflation uncertainty, Taiwan's monetary authorities alternatively behave an *stabilizing* policy to prevent economic damage from inflation uncertainty.

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