JEL Classification: C24, C45, E31
Keywords: inflation, inflation uncertainty, innovative distributions, Asian emerging markets

Bidirectional Nexus between Inflation and Inflation Uncertainty in the Asian Emerging Markets – The GARCH-in-Mean Approach

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Abstract

This paper investigates the bidirectional linkage between inflation and its uncertainty (inflation volatility) in the selected ten emerging Asian countries. In order to measure inflation uncertainty as accurate as possible, we consider GARCH-in-Mean model with six different distribution functions. We find the existence of the transmission effect from inflation to its volatility, but in the majority of the countries this effect is relatively week, amounting around 13% or way below. Only in the cases of Indonesia, China and Iran the effect is somewhat higher, with the magnitude of 26%, 20% and 17%, respectively. Evidence about the spillover effect from inflation uncertainty to inflation is reported only in four countries – Korea, Thailand, Pakistan and China. Interestingly, our results suggest that the highest impact from inflation volatility to inflation is found in Korea and Thailand, i.e. in the countries which implemented prudent and accountable inflation targeting strategy two decades ago. Complementary rolling regression supports the GARCH-in-Mean findings, providing an additional information about how the selected hypotheses manifest themselves in different subperiods.

1. Introduction

Finding an explanation about the nexus between inflation and its uncertainty became one of the focal points among the academics and policy makers since the seminal paper of Friedman (1977). He argued that higher inflation rate implies higher inflation uncertainty (inflation volatility), which in turn decreases public welfare and even output growth because of confused signals about the price changes. He explained that any attempt by the monetary authorities to achieve full employment through higher inflation would generate increased uncertainty about future inflation, and this uncertainty affects output adversely, since the price mechanism breakdowns. In other words, there is no stable trade-off between inflation and unemployment, which means that theoretical stance about the vertical Phillips curve not hold. In later research, Ball (1992) offered an additional evidence about the positive connection between inflation and inflation uncertainty that Friedman (1977) originally advocated. From that point on, this interdependence is well known in the economic literature as the Friedman–Ball hypothesis. Ball (1992) highlighted that existence of high inflation in the system is responsible for uncertainty about the future monetary policy. This happens because general public is unaware about the actions that monetary authorities may undertake when high inflation becomes a primary concern. As a consequence, this creates increased inflation uncertainty.

On the other hand, Cukierman and Meltzer (1986) took the other approach, they investigated how high inflation uncertainty leads to high inflation. They asserted that if high inflation uncertainty already exists among market participants, central bank may act opportunistically in an attempt to create inflation surprises to stimulate real economic growth. Hence, in these occasions, inflation uncertainty would positively influence inflation. The Cukierman–Meltzer hypothesis comes to the fore in an economy when the authority directs its attention more on economic growth than on inflation. This is the case for most of emerging economies, because policy-makers in these markets frequently put an extra stress on the economic growth over inflation stability (see Stavrev, 2008; Próchniak and Witkowski, 2014; Kilic and Arica, 2014).

However, the study of Holland (1995) showed that higher nominal inflation uncertainty can have a negative effect on the average inflation rate, because monetary authority tries to lower the money supply in order to eliminate inflation uncertainty and related negative effects on output. It happens because monetary authorities perceive inflation uncertainty too costly for the overall economic welfare, and then they focus their attention to reduce inflation uncertainty, which causes inflation to fall.

The focus of this paper is on emerging markets of South and East Asia, because according to Buth et al. (2015), most of the empirical works on this topic is devoted to developed countries, and less attention has been paid to emerging markets. According to Chen et al. (2018) and Wen et al., (2019) most of the selected emerging Asian economies are heavily dependent on oil import, whereby some authors found that inflation rates can vary widely with the changes in energy prices (see e.g. Stavrev 2006; Pažun et al., 2016; Živkov et al., 2019). Jongwanich and Park (2011) asserted that after both oil prices increase since 2003 and food price rise since 2006, commodity price shocks spiralled in emerging Asia, whereby these countries started to experience a surge in inflation during 2007 and 2008. Besides, our analysis covers relatively long time-span, also including Asian financial crisis 1997-1999, which caused heavy depreciation of many national currencies in East Asia. These depreciations consequently spilled over to the rising inflations in these countries. On the other hand, many emerging countries are firmly dedicated to pursue low inflation policy, which implied the adoption of the inflation targeting (IT) strategy (see e.g. Šmídková, 2005; Pelinescu and Caraiani, 2006; Daianu and Kallai, 2008; Babecky et al., 2009). As for the Asian countries, South Korea adopted IT in April 1998, Thailand in May 2000, the Philippines in January 2002, Indonesia in July 2005 and India in August 2016. Due to conflicting forces, which tries to push inflation upwards and downwards in the Asian countries, it is logical to raise the question whether the Friedman–Ball and Cukierman–Meltzer hypotheses hold in these countries. Therefore, the key motivation of this paper is to figure out whether these hypotheses are confirmed/refuted in the ten major emerging economies of South and East Asia – the Islamic Republic of Iran, Pakistan, India, China, South Korea, Thailand, Singapore, Malaysia, Indonesia and Philippines. At the same time, we try to highlight the monetary and economic peculiarities of the selected countries, which could explain why particular hypothesis comes to the fore.

In order to avoid identification problem, which may arise if inflation and its uncertainty are observed in two separate equations, we follow Fountas (2010), who investigated the nexus between inflation and inflation uncertainty simultaneously, increasing in this way efficiency of the estimation procedure. In particular, he used GARCH-in-Mean model, extended by the external regressor in the variance equation. This particular specification can unravel in the mean equation whether the Cukierman–Meltzer hypothesis holds, while in the variance equation, this is the case with the Friedman–Ball hypothesis. Also, it is well known that the interdependence between inflation and inflation uncertainty might be sensitive to how inflation uncertainty is measured, hence our goal is to gauge inflation uncertainty as accurate as possible. In that manner, we combine GARCH type model with several traditional and exotic distribution functions – normal, Student-t, generalized error distribution, normal inverse gaussian distribution, generalized hyperbolic distribution and Johnson SU distribution. This approach is in contrast to the abundance of studies that have used only the GARCH model with the ordinary normal distribution. Chen et al. (2008) argued that the major weakness of GARCH-normal type model is that it assumes a specific functional form before any estimations are made, which, as a result, could yield biased coefficient estimates and standard errors. The motivation behind the usage of these alternative, non-traditional distributions is the fact that they have theoretical advantages over the common normal distribution in modelling the tail distribution of inflation uncertainty, and as such, can potentially improve its assessment (see Lyu et al., 2017; Kresta and Tichy, 2012). Therefore, by applying different distribution functions in the GARCH-in-Mean model, we can determine which distribution function fits the best to the empirical time-series. Subsequently, the GARCH-in-Mean model with the optimal distribution is used to obtain the conditional variance, which serves as a proxy for inflation uncertainty.

To the best of our knowledge, this paper departs from the existing literature along several dimensions. First, this paper does a careful and rigorous quantitative inquiry about interaction between inflation and inflation uncertainty in a broad range of emerging Asian countries. Also, the uniqueness of this paper is the fact that we apply the GARCH-in-Mean model with several innovative distribution functions in an attempt to estimate inflation uncertainty as precise as possible, which never been done thus far. In addition, we conduct an additional analysis via rolling regression, which serves as a complementary analysis for the results obtained from the GARCH-in-Mean model. As far as we know, rolling regression was never used in the process of inflation-inflation uncertainty investigation.

Besides introduction, the rest of the paper is structured as follows. Second section presents literature review. Third section explains how inflation uncertainty is modelled and how the nexus between inflation and its uncertainty is examined via GARCH-in-Mean model. Fourth section is reserved for dataset presentation, while fifth section presents the results. Sixth section contains the results of the rolling regression, while the last section concludes.

2. Literature Review

The extant literature on the above-mentioned hypotheses provide rather mixed findings, and the reasons lie in the usage of different econometric techniques in the process of inflation uncertainty estimation, due to the choice of countries, the choice of sample period and data frequency. Since our paper is focused on the emerging Asian markets, this section is devoted to the findings about inflation-inflation uncertainty nexus, regarding only emerging markets around the globe.

For instance, Daal et al. (2005) researched the relation between inflation and inflation uncertainty for both developed and emerging countries, applying the asymmetric power GARCH model. Their results strongly support the Friedman–Ball hypothesis for both developed and emerging countries. They found that positive inflationary shocks have stronger impacts on inflation uncertainty in Latin American countries. Grier and Grier (2006) found that higher average inflation raises inflation uncertainty in Mexico, which confirms the Friedman–Ball hypothesis. They asserted that average inflation is harmful to Mexican growth due to its impact on inflation uncertainty. Thornton (2007) investigated 12 emerging market economies, using standard GARCH model for the construction of inflation uncertainty. He reported that higher inflation rates increased inflation uncertainty in all the economies, which gives strong support for the Friedman hypothesis. On the other hand, he claimed that the evidence on the effect of inflation uncertainty on average monthly inflation is more mixed. His evidence suggested that increased inflation uncertainty leads to lower average inflation in Colombia, Israel, Mexico, and Turkey, which is consistent with the Holland hypothesis, but to higher average inflation in Hungary, Indonesia, and Korea, which is in line with the Cukierman-Meltzer hypothesis. The study of Payne (2008) analysed the relationship between inflation and inflation uncertainty by examining three Caribbean countries: the Bahamas, Barbados, and Jamaica. Granger-causality tests indicated that an increase in inflation has been a positive impact on inflation uncertainty for each country, which is consistent with the Friedman hypothesis. On the other hand, an increase in inflation uncertainty produces a decrease in inflation in the case of Jamaica. Hasanov and Omay (2011) examined the relationships for ten CEE transition countries and they found overwhelming evidence which supports the Friedman–Ball hypothesis in eight out of ten countries, and the effect of the inflation rate on inflation uncertainty is not statistically different from zero in the two remaining countries. Živkov et al. (2014) investigated bidirectional linkage between inflation and its uncertainty by observing monthly data of eleven Eastern European countries and using quantile regression approach. According to the findings of these authors, both the Friedman and Cukierman–Meltzer hypotheses have been confirmed primarily for the largest EEC with flexible exchange rate. However, these theories are refuted in smaller, open economies with firm exchange rate regime.

As for the papers which focus only on the Asian markets, the findings are as follows. Chen et al. (2008) examined the causal relationship between inflation and inflation uncertainty in Taiwan, Hong Kong, Singapore and South Korea. They found overwhelming statistical evidence that Friedman hypothesis holds for these economies, but not for Hong Kong. In addition, they reported that Cukierman–Meltzer hypothesis is supported in all four economies. They concluded that the monetary authorities of these economies put a greater emphasis on growth rather than on inflation stability. The paper of Ozdemir and Fisunoğlu (2008) tested the Friedman and Cukierman-Meltzer hypotheses for the Jordanian, Philippine and Turkish economy. They used the parametric GARCH model to measure inflation uncertainty. Their findings supported the Friedman hypothesis, but they asserted that there is weak evidence which favours the Cukierman–Meltzer hypothesis. Jiranyakul and Opiela (2010) utilized the GARCH-type model and reported that both the Friedman–Ball and Cukierman–Meltzer hypotheses hold in five major ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand), covering relatively long time-period between 1970:01–2007:12. They concluded that even though these emerging markets have low inflation, inflation can lead to inflation uncertainty and uncertainty can lead to inflation. Dogru (2014) studied the relationship between inflation and inflation uncertainty in annual data in Turkey, covering the period between 1923-2012. He found evidence which supports the Friedman hypothesis in the long run that high inflation increases inflation uncertainty, but also, he reported that the Holland hypothesis is also valid in the short run, which propose that the increase in the inflation uncertainty decreases inflation. Buth et al. (2015) studied the relationship between inflation and inflation uncertainty in Cambodia, Lao PDR, and Vietnam, using a family of GARCH model for the estimation of inflation uncertainty. They reported that inflation causes inflation uncertainty in these countries, which supports the argument of the Friedman hypothesis. Also, they demonstrated that inflation uncertainty causes inflation only in Lao PDR, which supports Cukierman and Meltzer's argument.

3. Research Methodology

Our goal is to precisely measure the monthly inflation uncertainties and, at the same time, to overcome biased estimates, which can be caused by an identification problem. In that manner, we consider GARCH-in-Mean specification, which can assess the Friedman–Ball and Cukierman–Meltzer hypotheses jointly. In order to be as accurate as possible in the computational process, we additionally consider several alternative distributions – normal (norm), Student-t (std), generalized error distribution (ged), normal inverse gaussian distribution (nig), generalized hyperbolic distribution (ghyp) and Johnson SU distribution (jsu)[1]. Spurious regression in the mean process, which can be caused by autocorrelation, is avoided by inserting AR(1) specification in the mean equation for all the selected inflation series. According to Fountas (2010), the mean and variance equations in the GARCH-in-Mean process, with the external regressor in the variance equation, are given as in equations (1) and (2):

$$\pi_t = \Phi + \Theta\pi_{t-1} + \Psi h_t + \varepsilon_t, \qquad \varepsilon_t \sim i.i.d.(0, h_t) \tag{1}$$

$$h_t = \phi + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \delta\pi_{t-1} \tag{2}$$

where π is the inflation rate computed as first difference of logarithm of consumer price index (CPI). h_t is the conditional variance with the conditions $\phi \geq 0, \alpha \geq 0$ and $\beta \geq 0$. According to Jiranyakul and Opiela (2010), the GARCH measure of inflation uncertainty mostly comply to the notion of inflation uncertainty expressed by Friedman and Ball. The error term (ε_t) follows the $i.i.d.$ process, and the usage of optimal distribution is primarily in our focus.

Therefore, besides three traditional distribution functions – normal $\varepsilon \sim N(0, h_t)$, Student-t $\varepsilon \sim St(0, h_t, \nu)$ and generalized error distribution $\varepsilon \sim GED(0, h_t, k)$, we also consider three complex, unconventional heavy tailed distributions – normal inverse Gaussian distribution of Barndorff-Nielsen (1997), generalized hyperbolic distribution of Barndorff-Nielsen (1977) and Johnson SU distribution of Johnson (1949). These

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[1] Estimation of GARCH-in-Mean model with several alternative distributions was done via the 'rugarch' package in 'R' software.

uncommon distributions can recognize heavier tails than the normal distribution, which are often skewed and asymmetric, having one heavy, and one semi-heavy or more Gaussian-like tail.

According to Barndorff-Nielsen (1997), the normal inverse Gaussian (NIG) distribution is a generalised hyperbolic distribution presented as in equation (3):

$$f(x) = \frac{\delta\alpha \exp\left(\delta\sqrt{\alpha^2-\beta^2}\right)K_1\left(\alpha\sqrt{\delta^2+(x-\mu)^2}\right)\exp\left(\beta(x-\mu)\right)}{\pi\sqrt{\delta^2+(x-\mu)^2}}; \qquad (3)$$

$$x \to \pm\infty$$

where $\delta > 0$ and $0 < |\beta| \leq \alpha$. Scale and location are determined by the μ and δ parameters, respectively. Shape and density are controlled by α and β parameters, respectively. K_1 is modified Bessel function of the third kind. Symmetric distribution happens if $\beta = 0$.

Generalized hyperbolic (GH) distribution of Barndorff-Nielsen (1977) has a form:

$$f(x) = \frac{\left(\alpha^2-\beta^2\right)^{\lambda/2} K_{\lambda-1/2}\left(\alpha\sqrt{\delta^2+(x-\mu)^2}\right)\exp\left(\beta(x-\mu)\right)}{\sqrt{2\pi}\alpha^{\lambda-1/2}\delta^{\lambda}K_{\lambda}\left(\delta^2\sqrt{\alpha^2-\beta^2}\right)\left(\sqrt{\delta^2+(x-\mu)^2}\right)^{\frac{1}{2}-\lambda}} \qquad (4)$$

where $\delta > 0$ and $0 < |\beta| \leq \alpha$. Scale and location are determined by the μ and δ parameters, respectively. Shape and density are controlled by α and β parameters, respectively. K_1 is modified Bessel function of the third kind. In GH distribution, parameters must fulfil the following conditions:

$$\begin{array}{lll} \delta \geq 0, |\beta| < \alpha & \text{if} & \lambda > 0 \\ \delta > 0, |\beta| < \alpha & \text{if} & \lambda = 0 \\ \delta > 0, |\beta| \leq \alpha & \text{if} & \lambda < 0 \end{array} \qquad (5)$$

At the end, Johnson SU distribution of Johnson (1949) is described as in equations (6) and (7):

$$f(x) = \frac{\tau}{\sigma(s^2+1)^{1/2}\sqrt{2\pi}}\exp\left[-\frac{1}{2}z^2\right] \qquad (6)$$

$$z = \nu + \tau\sinh^{-1}(s) = \nu + \tau\log\left[s + (s^2+1)^{1/2}\right] \qquad (7)$$

where $-\infty < x < \infty, -\infty < \mu < \infty, -\infty < \nu < \infty, \sigma > 0, \tau > 0$.

4. Dataset and the Construction of the Inflation Uncertainty Time-Series

This paper uses monthly time-series of consumer price index (CPI) for ten major emerging markets of South and East Asia – the Islamic Republic of Iran, Pakistan, India, China, South Korea, Thailand, Singapore, Malaysia, Indonesia and Philippines. Inflation rates (π_t) for these countries are calculated according to the expression: $\pi_t = 100 \times (CPI_t/CPI_{t-1})$. All inflation time-series are seasonally adjusted, using filter-based methods of seasonal adjustment, known as X11 style method. The sample ranges from January 1990 to January 2019, and all time-series are collected from the IMF World Economic Outlook database. Table 1 gives descriptive statistics of the selected inflation rates, and it could be seen that Iran has the highest average inflation, while Indonesia and Pakistan follow. The majority of the selected inflations reports high skewness and kurtosis values, which heavily exceed the reference values of the normal distribution (equal to 0 and 3). This might suggest that some non-traditional distributions might be appropriate for the empirical inflation rates. Dickey-Fuller test with generalized least squares indicate that all inflation time-series have no unit root, which makes them suitable for modelling in the GARCH process.

Table 1 Descriptive Statistics of the Selected Monthly Inflations

	IRN	PAK	IND	CHN	KOR	THA	SGP	MYS	IDN	PHL
Mean	1.498	0.670	0.602	0.330	0.291	0.247	0.139	0.222	0.733	0.455
St. dev.	1.133	0.614	0.648	0.598	0.353	0.418	0.335	0.358	1.191	0.470
Skewness	1.777	0.638	0.969	1.575	1.391	-0.478	-0.214	2.815	5.271	2.574
Kurtosis	8.234	4.284	6.832	7.908	8.552	14.108	6.886	32.958	39.235	15.713
JB test	580.4	47.5	267.4	493.2	559.1	1802.3	221.7	13473.1	20649.3	2727.8
DF-GLS test	-2.983	-2.964	-12.405	-2.163	-11.734	-8.748	-7.258	-12.510	-5.468	-2.516

Notes: 1%, 5% and 10% critical values for Dickey-Fuller test with generalized least squares (DF-GLS), with 5 lags and assuming only constant, are -2.571, -1.941 and-1.616, respectively.

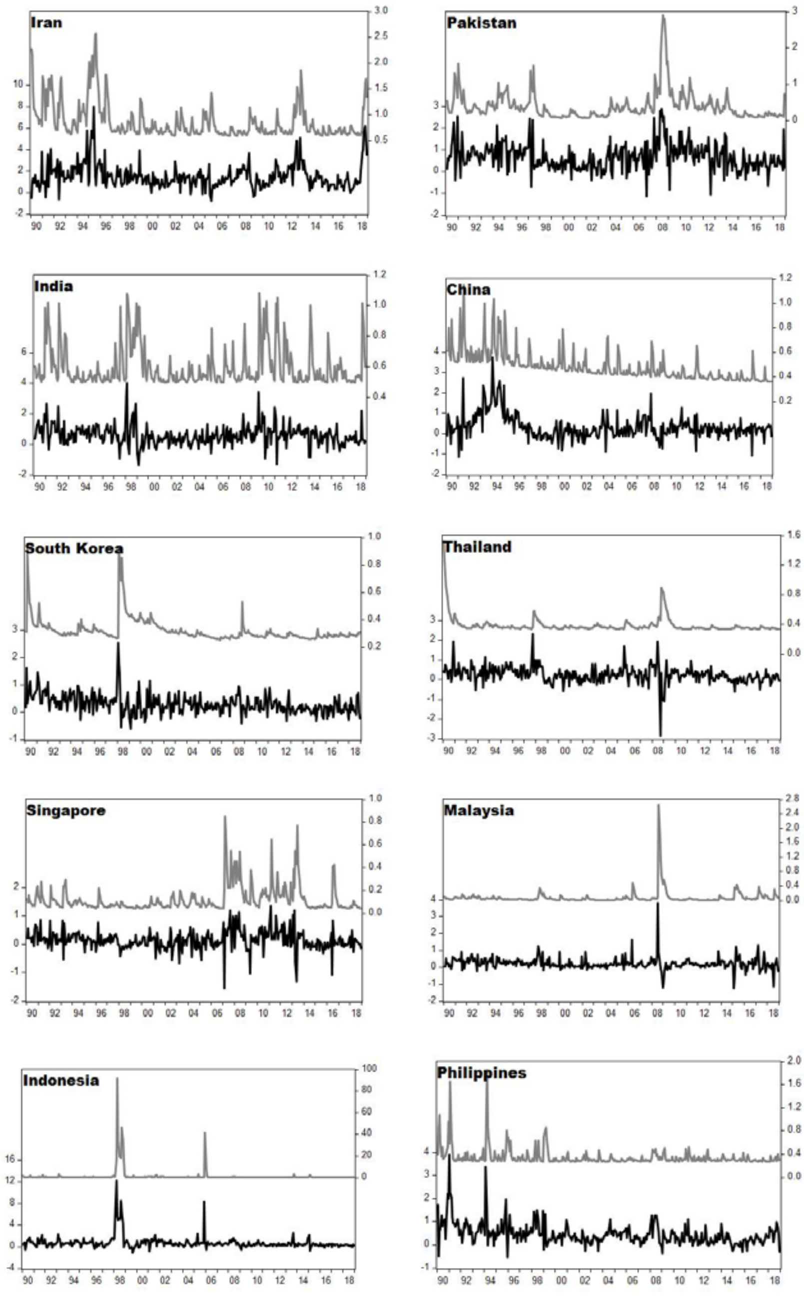
The next task is to find out which distribution function in the GARCH-in-mean model fits the best to the empirical time-series, which will be used for proxying inflation uncertainty by the conditional variance of inflation. For that cause, we calculate AIC values for every model specified. The model with the lowest AIC coefficient suggests that this model is the most favourable for the creation of conditional variance, which is subsequently inserted in the mean equation of the model. Table 2 presents calculated AIC values.

Table 2 Estimated AIC Values for the Selected GARCH Models

	IRN	*PAK*	*IND*	*CHN*	*KOR*	*THA*	*SGP*	*MYS*	*IDN*	*PHL*
GARCH-norm	2.477	1.678	1.798	1.290	0.588	0.829	0.519	0.726	2.211	0.799
GARCH-std	2.416	1.649	1.680	1.201	0.463	0.634	0.408	0.036	1.349	0.539
GARCH-ged	2.419	1.653	1.706	1.206	0.497	0.667	0.418	0.078	1.464	0.584
GARCH-nig	2.391	1.650	1.685	1.203	0.461	0.652	0.406	0.012	1.376	0.509
GARCH-ghyp	2.396	1.656	1.686	1.209	0.456	0.646	0.413	0.015	1.352	0.506
GARCH-jsu	2.393	1.651	1.683	1.203	0.457	0.644	0.407	-0.002	1.352	0.505

Notes: Greyed values denote the lowest AIC values.

Figure 1 Monthly Inflation Conditional Volatilities and Inflation Rates for the Selected Countries



Notes: Greyed lines denote conditional volatilities obtained from the optimal GARCH model, and they stand as a proxy for inflation uncertainty. Blacked lines represent empirical inflation rates.

Table 2 shows that the lowest AIC results are heterogeneous across the countries, which justifies our usage of the GARCH model with various distribution specification for the calculation of inflation uncertainty series. It can be seen that GARCH-std model is an optimal model in five out of ten cases. The GARCH with normal inverse Gaussian (NIG) distribution and Johnson SU distribution is optimal in two cases, while generalized hyperbolic (GH) distribution has an upper hand in one case. GARCH model with the traditional normal distribution is not optimal for any of the selected countries.

Based on the results in Table 2, we estimate GARCH-in-mean models, using optimal distributions. We present the constructed conditional volatilities obtained from the optimal GARCH-in-Mean model as well as corresponding empirical inflation rates in Figure 1. Combining the findings in Table 1 and Figure 1, it could be concluded that inflation rates of the selected Asian markets demonstrate unstable and erratic dynamics throughout the observed period. These findings justify our approach to use several traditional and innovative distribution functions in the GARCH-in-Mean model.

5. Empirical Findings

This section presents the results of the estimated GARCH-in-Mean models in the ten major emerging markets of South and East Asia. This model can unravel jointly the bidirectional interdependence structure between inflation and its uncertainty in these countries. In particular, in the mean equation (Panel A of Table 3), parameter Ψ measures the transmission effect from inflation uncertainty to inflation (the Cukierman–Meltzer hypothesis), while in the GARCH equation (Panel B of Table 3), parameter δ can tell us how inflation affects inflation uncertainty (the Friedman–Ball hypothesis). All GARCH-in-Mean models are estimated with the optimal distribution function, according to the lowest AIC values, which are presented in Table 2. Panel C contains estimated distribution parameters, and it can be seen that all distribution parameters are highly statistically significant, which corroborate validity of the used distributions. Panel D contains Ljung-Box Q-statistics for level and squared residuals and shows that all models have no problem with serial correlation or heteroscedasticity, which speaks in a sake of models' adequacy.

Table 3 Estimated Parameters of GARCH-in-Mean Models for the Selected Asian Countries

	IRN	PAK	IND	CHN	KOR	THA	SGP	MYS	IDN	PHL
Panel A: Mean equation specification										
Φ	1.599***	0.324***	0.396**	0.083	-0.214	0.006	0.001	0.254***	0.452***	0.345***
Θ	0.597***	0.364***	0.330***	0.433***	0.273***	0.351***	0.134*	0.273***	0.434***	0.533***
Ψ	-0.308	0.506*	0.238	0.315*	1.631***	0.609*	0.410	-0.172	0.077	0.065
Panel B: GARCH equation specification										
ϕ	-0.028	0.012	-0.003	0.082***	0.012*	0.015	0.031***	0.091**	0.016	0.002
α	0.256***	0.197**	0.153***	0.138***	0.187***	0.110***	0.447***	0.010**	0.623**	0.079***
β	0.497***	0.523***	0.780***	0.691***	0.551***	0.696***	0.242***	0.589***	0.216***	0.683***
δ	0.166***	0.132***	0.107***	0.200***	0.056***	0.048**	0.082***	-0.077***	0.259***	0.068***
Panel C: Distribution parameters										
Shape	1.64***	6.77***	5.09***	4.20***	0.25***	4.03***	0.81***	0.99***	2.91***	1.46***
Skew	0.35***	—	—	—	0.98***	—	0.13***	0.46***	—	0.69***
Panel D: Diagnostic tests										
LB(Q)	0.539	0.453	0.949	0.431	0.777	0.447	0.334	0.752	0.147	0.208
LB(Q^2)	0.926	0.741	0.842	0.663	0.938	0.888	0.742	0.915	0.940	0.975

Notes: LB(Q) and LB(Q2) test denote p-values of Ljung-Box Q-statistics for level and squared residuals for 5 lags. ***, **, * represent statistical significance at the 1%, 5% and 10% level, respectively.

5.1 The Friedman–Ball Hypothesis – Results Discussion

Observing the GARCH equation parameters, particularly the δ parameter, we can see that the effect of the Friedman–Ball hypothesis exists in all the countries, but it should be emphasized that this effect is relatively week in most of the countries. Finding the presence of the Friedman–Ball hypothesis coincides very well with other studies, which investigated Asian countries, and also reported a positive relationship between the variables (see e.g. Chen et al., 2008; Jiranyakul and Opiela, 2010; Jiranyakul and Opiela, 2011). However, it should be underlined that our analysis is based on more accurate approach in comparison to the results of the aforementioned papers, because we estimate GARCH model with different complex and elaborate distributions in order to measure inflation uncertainty. On the other hand, Jiranyakul and Opiela (2010) and Jiranyakul and Opiela (2011) applied traditional GARCH-normal model for the creation of inflation uncertainty series, which could yield biased estimates, since we demonstrated that GARCH models with more elaborate distributions better explain the inflation uncertainty process. In addition, Chen et al. (2008) took the measurement of the moving average standard deviation as a proxy for inflation uncertainty, which is also a simple and not much reliable method.

As for the estimated δ parameters, it can be viewed that all these parameters are highly statistically significant, but relatively low, whereby only in the cases of Indonesia, China and Iran, we find that 100% increase in inflation causes 26%, 20% and 17% rise in inflation uncertainty, respectively. Only in the cases of Pakistan and India, this effect goes slightly above 10%, whereas in all other cases, this influence is well below 10%. It is interesting to notice that these five economies have the highest average inflation, according to Table 2, and high inflation is the main culprit for high inflation uncertainty, as the Friedman–Ball hypothesis proposes. Besides, low and relatively low δ findings may suggest that, in the most cases, monetary authorities of the Asian countries conduct prudent and accountable anti-inflationary policy, not allowing spillover from inflation to inflation uncertainty, which may generate adverse inflation expectations in the future.

Regarding the cases with the highest δ parameters (Indonesia, China and Iran), one could find surprising that Indonesia has the highest δ, since Indonesia is a country which adopted IT policy almost 15 years ago, in July 2005. High transmission effect from inflation to its volatility and the commitment to IT policy should not go hand in hand, because some authors, such as Tas (2012) and Tas and Ertugrul (2013) claimed that IT countries achieve lower inflation uncertainty, than non performing IT countries. Taguchi and Kato (2011) offered a rational explanation for Indonesia. They stated that Indonesia implemented backward-looking policy under inflation targeting regime, which had poor effect in terms of price stabilisation. They asserted that important factor is private sector perception about inflation expectations. According to these authors, backward-looking rule is frequently accompanied by unreliable inflation forecasting, which makes much harder for private agents to recognize the true intentions of central bank, and as a result inflation uncertainty rises. Contrary to the Indonesian case, Korea adopted forward-looking policy under inflation targeting, which is a successful policy from the price stability point of view. Our results are in line with this claim, since we find that inflation impacts its volatility by 5.6% in the Korean case, which is very low. As a matter of fact, Korean δ parameter is the second lowest, while Thailand has the lowest δ parameter (4.8%), and this country pursue IT policy, since 2000. It should be said that Philippines also conducts IT, and we can witness that in this case δ parameter is also very low (6.8%).

As for the case of China, Table 1 reports that China had relatively high average inflation, but the lowest of the top five countries with the highest inflation. Regardless of this, we find that the Friedman–Ball effect is the second largest in the Chinese case, amounting 20%. According to Zhang (2013) inflation in China is Granger-caused by monetary growth in both the short and the long run. However, it should be said that China is bit specific country since China is the second-largest world economy with the fastest growth over the past three decades. In that regard, one of the main goals of the Chinese government is achieving and maintaining high and stable economic growth. Relatively high money growth is one of the primary instruments for economic growth instigation. Zhang (2013) contended that it inevitably raises a concern for Bank of China how to accomplish effective trade-off between inflation uncertainty and business cycle uncertainty. This is the probable reason why inflation influences inflation uncertainty in China and why we find relatively high δ parameter.

In the Iranian case, Table 3 suggests that 100% increase in Iranian inflation transfers to Iranian inflation uncertainty in 17%. Probable reason for such relatively high spillover effect is the fact that Iran has the highest average inflation rate in comparison to all other selected countries, as Table 1 indicates. To be more specific, Iranian inflation is double the size of the second highest inflation (Indonesian inflation), which is also high. High Iranian inflation is an aftermath of numerous endogenous and exogenous factors. As Kia (2006) contended, higher exchange rate leads to a higher price in Iran in the long run, but also the increase in the real government expenditures and government deficits cause inflation to rise in Iran. Besides, Iran was/is affected by Western sanctions for number of years, which negatively influenced its oil export, and forced Iranian government to generate budget deficits. All these factors eventually end up in a higher inflation, which inevitably spills over to higher inflation uncertainties, which is confirmed by our results.

5.2 The Cukierman–Meltzer Hypothesis – Results Discussion

Parameter Ψ in the mean equation in Table 3 explains the transmission effect from inflation uncertainty to inflation. In relation to δ parameters, which are all highly statistically significant, we find that Ψ parameters are significant only in 4 out 10 cases – Korea, Thailand, Pakistan and China. Finding evidence of the Cukierman–Meltzer hypothesis means that monetary authorities most likely tend to put a greater emphasis on output growth than on inflation stability.

As we explained in previous subsection, this scenario is particularly characteristic for China. Zhang (2013) contended that in China exist strong and stable relationship between monetary growth and output growth. On the other hand, monetary growth is the dominant driving force of inflation, whereby any deviation of real money growth from its long run trend presents a good indicator of future inflation acceleration or deceleration. These facts probably explain why inflation uncertainty have relatively strong impact on inflation in China.

In the case of Pakistan, parameter Ψ is even higher, and the explanation why this is the case could be found in the paper of Kim and Lin (2012). These authors argued that in countries with less credible monetary policy and poor institutions such as less independent central bank, inflation volatility has a larger influence on inflation. Also, they asserted that in countries with lower incomes and weak fiscal discipline, which is mirrored in higher fiscal deficits and higher government debts, inflation volatility has larger influence on inflation. Pakistan is a developing country, and all these arguments listed by Kim and Lin (2012) are in line with the Pakistani characteristics, providing an explanation why inflation volatility affects inflation in this country in relatively high rate. On the other hand, Philippines and Iran are also developing countries and have relatively similar institutional and macro-features as Pakistan, but GARCH-in-Mean model fails to find evidence of the Cukierman–Meltzer hypothesis. This model can yield only static parameter estimates, which, obviously, is not enough to find an evidence of the Cukierman–Meltzer hypothesis. This is the reason why we additionally apply rolling regression in the next section.

As for Korea and Thailand, it is interesting to note that these countries experience the highest effect from inflation volatility to inflation, according to Table 3. In the first glance, these results might seem a little bit odd, because Korea and Thailand have one of the lowest inflation rates (see Table 1), and they implemented IT strategy almost two decades ago. Inflation targeting policy is known to put a greater emphasis on central banks' transparency, credibility, and accountability in conducting monetary policy, with primary goal to reduce an inflation bias and increases the likelihood of maintaining low and stable inflation. However, as Kim and Lin (2012) asserted, inflation uncertainty, actually, has a greater effect in countries that practice inflation targeting, than in countries with some alternative policy frameworks. This happens because general public have high expectations about achieving planned inflation goals in inflation targetters, and any departure from this path increases inflation more rigorously, than in the cases when such high expectations are non-existent. This explanation fits very well with our results, because in countries which conduct some other disinflationary policies, such as Singapore, Malaysia and India[2] or non-credible IT strategy, such as Indonesia, we do not find that inflation uncertainty has any effect on inflation, according to GARCH-in-Mean model.

6. Complementary Analysis Via Rolling Regression

In order to add to the robustness of the GARCH-in-Mean parameters, and at the same time to put more credibility to our findings, we conduct an additional analysis via rolling regression. We apply rolling regression approach because of the fact that Table 3 contain only average values of δ and Ψ parameters, and it is hard to believe that these parameters have the same value throughout the observed sample. The idea to use rolling regression was borrowed from Andion et al. (2010), Adam et al. (2012), Errit and Uusküla (2014), Stakėnas and Stasiukynaitė (2017) and Mirović et al. (2017). This methodology can test whether results are driven by a particular sample period or not. The size of the rolling window is set to be four years, i.e. 48 monthly observations, meaning that the number of consecutively calculated rolling spillover parameters is 300 for every country. We use generalized least square (GLS) approach for the rolling regression estimation, with aim to correct standard errors for autocorrelation and thus

[2] India adopted IT strategy in August 2016, which is a way too short period to draw any conclusions about this strategy in our econometric model.

avoid possible spurious regression. In addition, we apply the White method for heteroscedasticity, which was proposed by MacKinnon and White (1985). In order to avoid identification problem, we add autoregressive term in equations (8) and (9)[3]. The rolling regression equations for both hypotheses look like as follows:

$$h_t = \omega_{0t} + \omega_{1t} h_{t-1} + \omega_{2t} \pi_t + \varsigma_t, \qquad \varsigma_t \sim N(0, \sigma^2_{t,h}) \tag{8}$$

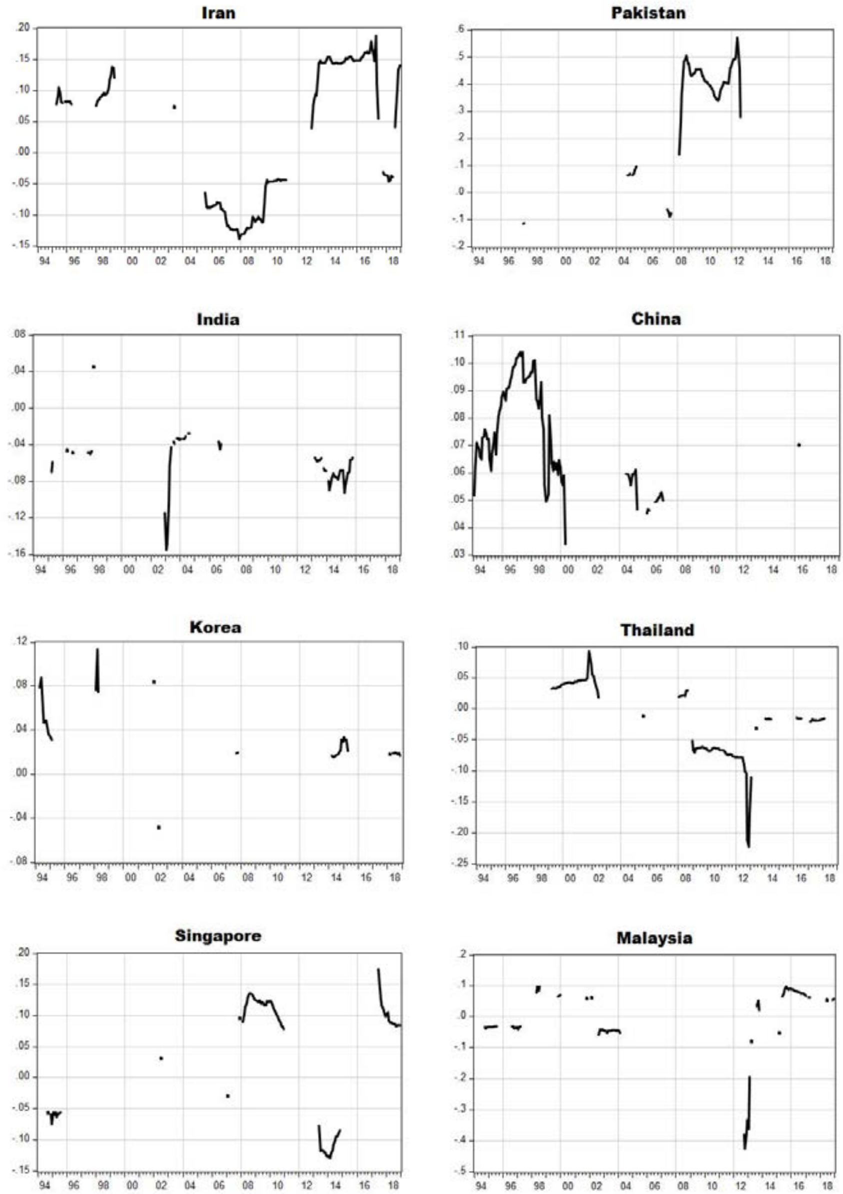
$$\pi_t = \lambda_{0t} + \lambda_{1t} \pi_{t-1} + \lambda_{2t} h_t + \zeta_t, \qquad \zeta_t \sim N(0, \sigma^2_{t,\pi}) \tag{9}$$

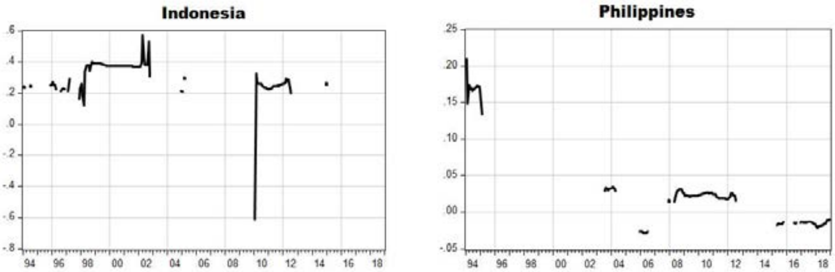
We are primary interested in time-varying ω_{2t} and λ_{2t} parameters, which give us a clue about the dynamic transmission effect from inflation to inflation uncertainty, and vice-versa. Figures 2 and 3 contain only estimated statistically significant rolling parameters for the Friedman–Ball and Cukierman–Meltzer hypotheses, respectively, while statistically insignificant parameters are omitted. Both Figures, 2 and 3, suggest that rolling parameters are only sporadically significant, and this is the reason why plots resemble to broken lines.

We have reported in Table 3 that in the cases of Indonesia, China and Iran, the Friedman–Ball effect is the strongest. The rolling estimates confirm these previous findings, but additionally tell us in which particular periods these parameters are detected. For instance, in the case of Iran, we find relatively high rolling parameters in the period between 2013-2016. This is the period when annual inflation rate in Iran went over 30% (see Figure 1), and this happened due to international economic sanctions, imposed over Iran's disputed nuclear programme. For the Chinese case, we find relatively high ω_{2t} parameters around the period 1993-1996. According to Zhang (2013), China aggressively loosened credit control in 1992 in order to encourage investment, which caused record money supply growth rate of 48%, spurring Chinese inflation to reach its peak of 24% in 1994. Chinese rolling parameters perfectly fit to these facts. As for Indonesia, we find positive rolling parameters only around the Asian crisis, when Indonesian rupiah suffered terrible depreciations, which induced a rise in inflation over 60% in this country. In the case of Pakistan, positive rolling parameters can be spotted only around the global financial crisis 2008-2010, when Pakistani rupee depreciated significantly, which probably caused high inflation in this country (see Figure 1), and the transmission effect to its volatility. In all other countries, we find very weak evidence of the Friedman–Ball hypothesis, which coincides well with the estimated δ parameters in Table 3.

[3] We thank anonimous referee for this useful comment.

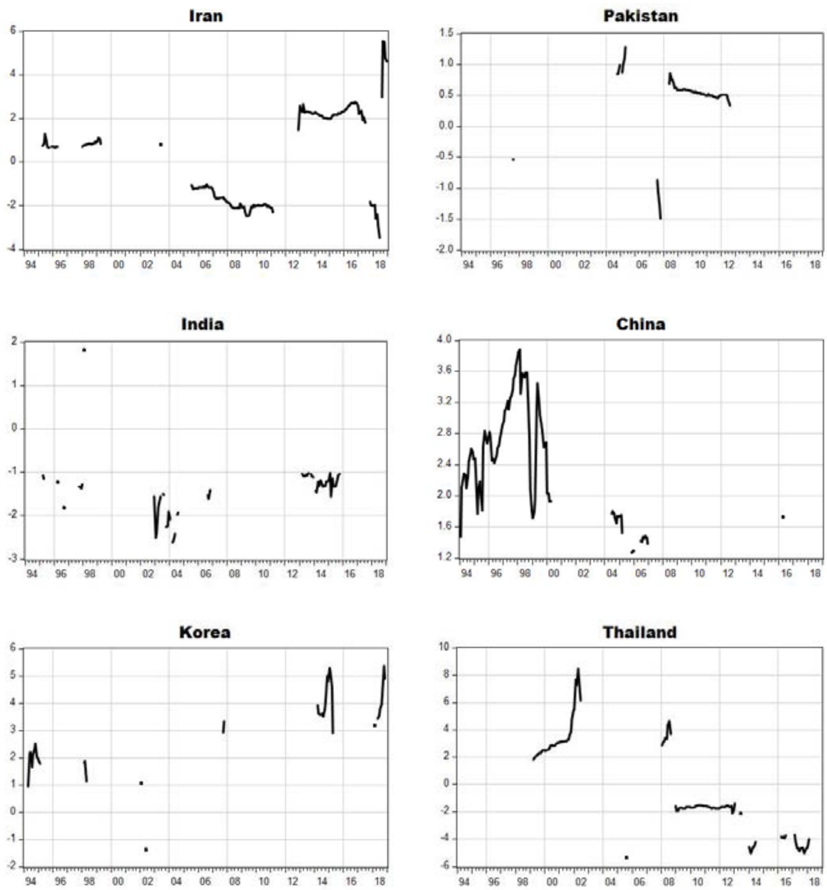
Figure 2 Rolling Parameter Estimates for the Friedman–Ball Hypothesis

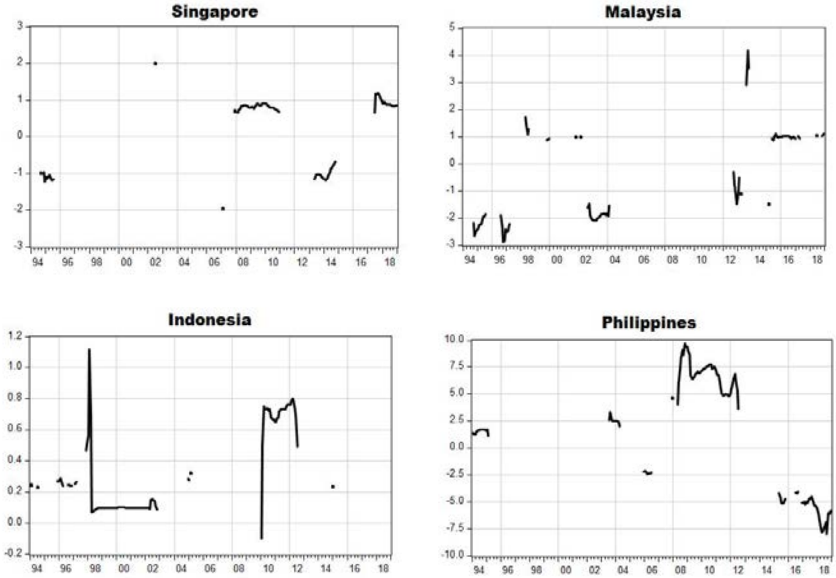




Notes: The estimated rolling parameters are considered significant only if their p-value is less than 10%.

Figure 3 Rolling Parameter Estimates for the Cukierman–Meltzer Hypothesis





Notes: The estimated rolling parameters are considered significant only if their p-value is less than 10%.

Figure 3 depicts rolling estimates for the Cukierman–Meltzer hypothesis, and it is obvious that majority of the estimated parameters are not significant. Our GARCH-in-Mean findings suggest that only in the cases of Korea, Thailand, Pakistan and China spillovers from inflation uncertainty to inflation occur. These results are pretty much confirmed by the rolling estimates, except for the case of Korea. In addition, we expressed doubt about not finding statistically significant Ψ parameters for Iran and Philippines in section 5.2., which conflicts with the assertion of Kim and Lin (2012). These authors claimed that in low income countries with less credible monetary policy, poor institutions and weak fiscal discipline, inflation volatility has a larger influence on inflation. Therefore, it is a bit surprising because we find insignificant Ψ parameters in theses countries. However, rolling parameters indicate that strong presence of the Cukierman–Meltzer hypothesis can be spotted in the Iranian case around 2013-2015, whereas in the Filipino case it is between 2008-2013.

7. Conclusion

This paper analyses the bidirectional interdependence between inflation and inflation uncertainty in ten emerging Asian countries, i.e. we put to the test the two hypotheses – Friedman–Ball and Cukierman–Meltzer. The first one implies that higher inflation rate leads to higher inflation uncertainty, while the other one proposes that higher inflation uncertainty causes higher inflation. Our intention is to accurately measure inflation uncertainty, which enables us to avoid biased parameter estimates and spurious conclusions. In that context, we employ GARCH-in-Mean model with six different distribution functions, which allow us to estimate both hypotheses jointly as well as to avoid an identification problem.

According to the estimated parameters, we find evidence of the Friedman–Ball hypothesis in all the countries, but only in the cases of Indonesia, China and Iran the transmission effect from inflation to its volatility is relatively high. In the case of Indonesia, the Friedman–Ball effect is the highest, amounting 26%. The rationale lies in the fact that Indonesia implemented backward-looking policy under IT regime, which has weak effect in terms of price stabilisation and conveying information about inflation expectation to private sector. In China, one of the primary instruments for economic growth instigation is the money growth, which inevitable spills over to inflation uncertainty. As for Iran, this country is overloaded with numerous internal and external problems, such as unstable exchange rate, government deficits, volatile price of oil, Western sanctions, etc. All these factors cause high inflation, which eventually spills over to higher inflation uncertainties, as our results indicate.

Evidence about the Cukierman–Meltzer hypothesis is found only in four countries – Korea, Thailand, Pakistan and China. Interestingly, our results suggest that the highest effect from inflation volatility to inflation is recorded in Korea and Thailand, which started to conduct IT strategy two decades ago. However, it is not surprising to find strong Cukierman–Meltzer effect in countries which adopted IT strategy. This happens because any departure from expected inflation targets increases inflation significantly. Pakistan characterises less credible monetary policy, poor institutions and weak fiscal discipline, and in low income countries, such as Pakistan, inflation volatility has relatively large influence on inflation. Complementary rolling regression supports the GARCH-in-Mean findings, providing an additional information how the selected hypotheses manifest themselves in different subperiods.

The results of this paper could be useful for monetary authorities of the selected countries, because it could provide an insight about the intrinsic connection between inflation and inflation uncertainty. As for wider audience, the results from this paper indicate that, in the most cases, monetary authorities of the selected countries pursue prudent and accountable policy, which suppresses both inflation and inflation uncertainty, and prevents negative effect on the overall economic welfare, which high inflation and inflation uncertainty might have.

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