Quantitative Finance and Economics

QFE, 8(2): 235–254.
DOI: 10.3934/QFE.2024009
Received: 16 January 2024
Revised: 02 April 2024
Accepted: 10 April 2024
Published: 17 April 2024

https://www.aimspress.com/journal/QFE

Research article

Growth volatility in the inflation-targeting regime: Evidence from Indonesia

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Abstract: Low and stable inflation and exchange rates are the main objectives of inflation-targeting monetary policy. The internal and external stabilities are prerequisites for promoting economic growth. Using a two-stage GARCH, we investigated the effect of inflation instability and exchange rate unpredictability on the economic growth uncertainty in the case of Indonesia over the period 2000(1)–2022(12). It was evident that both inflation instability and exchange rate unpredictability hurt output growth. The impact of inflation instability was higher than that of exchange rate unpredictability. While the output growth was higher in the post inflation-targeting regime adoption, the effect of real exchange rate instability was greater than that of nominal exchange rate unpredictability. Those findings suggested that the monetary authority should strengthen their commitment to achieve the inflation target range. The sharper focus on the inflation stability might avoid the monetary authority conducting twofold targets of inflation and exchange rate stability to stimulate economic growth.

Keywords: inflation targeting; inflation volatility; exchange rate volatility; growth convergence; two- stage GARCH

JEL Codes: E52, E58, F31, G15, O47

1. Introduction

Since the early 1990s, the inflation targeting (IT) framework has become the dominant monetary policy regime both in developed and emerging economies (Svensson, 1999). By removing discretion into rule-based monetary policy, the introduction of the IT regime is expected not only to maintain the inflation rate within the target range but also reduce its volatility. While the reduction of inflation rate both at the level and its volatility after adopting the IT regime have received conventional wisdom (Ha et al., 2019; Cabral et al., 2020), its role on the exchange rate volatility alleviation remains questionable.

Despite IT keeps providing the best outcomes in the form of lower exchange rates volatility (Berganza & Broto, 2012), the exchange rate in IT regime economies is more volatile than in advanced economies (Chițu & Quint, 2018). The low degree of exchange rate pass-through (ERPT) in the IT regime leads to destabilizing the inflation rate, which in turn suppresses its external value (Kuncoro, 2015). In the financial markets, interest rates do not always equal the relative change in exchange rates. As a result, the policy rate as the primary tool in IT monetary policy fails to manage future inflation expectation and is ineffective to control the exchange rates instability (Kuncoro, 2020).

In line with the stabilization issues, whether the IT regime could act as a prerequisite to stimulate output growth is also challenging. Contracts among economic agents are generally made at the nominal forms, resulting in unpredictability in future price level changes that require higher risk premia to accommodate unexpected changes in the wealth distribution (Fielding, 2008). The high inflation volatility leads to higher economic costs and depresses economic growth (Mandeya & Ho, 2022). However, inflation volatility in countries, which have better economic environments and institutional conditions could induce higher economic growth (Dotsey & Sarte, 2000; Blanchard & Simon, 2001).

In contrast, structural economists propose that exchange rate can have a negative impact on economic growth. The domination of imported input in the structure of production in emerging economies leads to an increase in exchange rates adversely affecting economic growth. The classical paradigm argues that an increase in exchange rates amplifies the export promotion, enlarges investment, attracts investment inflow, and stimulates import substitution (Aman et al., 2017), which in turn increases the aggregate demand. As the IT emerging countries suffer higher external risk exposure, the exchange rate stability becomes a more important monetary policy instrument to achieve stable economic growth.

The sharper focus on the exchange rate stability may also complicate their policy implementation (Adler et al., 2021). The distorted commitment to achieve the inflation target compared to the exchange rate target raises a concern about the need for policy reformulation to rebalance stabilization strategies toward sustainable economic growth. Nevertheless, few studies focus on the impact of the IT monetary policy on economic growth. Those separate works have not yet considered their joint effect. Hence, there is no general consensus on how inflation variability and exchange rates instability affect the output growth volatility, which needs further explorations.

So far, there is little research on economic growth volatility (Bhandari & Frankel, 2017; Benchimol & Fourçans, 2019; Benchimol & Ivashchenko, 2021). Most research focuses on the external economy, global fluctuations, and fluctuations in domestic financial markets. Moreover, there is limited research that addresses the theme of monetary policy as a source of uncertainty. In fact, monetary policy plays an important role in conditioning price and exchange rate stability as a foundation for economic growth.

Indonesia offers a good case for discussing those issues. Suffering the soared inflation rate, minus output growth, and dramatic exchange rate depreciation following the 1997–1998 Asian monetary crisis have led Indonesia' monetary authority to implement various economic recovery programs along with institutional reforms. Since 1999, Indonesia has been implementing a new law Act No. 23/1999 for the central bank. With respect to the stabilization agendas, the central bank began setting the inflation target in 2000 at the time the IT regime unofficially adopted. The monetary policy frameworks then fully switched into the IT regime in July 2005.

In relation to the central bank independence, the monetary authority eliminated capital controls, abolished interest rate arrangements, adopted a flexible exchange rate regime, and deliberated almost the entire financial system. All the fundamental changes are made to achieve a stable Rupiah (Indonesian currency) both in terms of domestic prices and foreign currency, a single goal as assigned by the new law of the central bank. As a result, during the 2008 global financial crisis, Indonesia experienced low inflation and stable exchange rates relative to the 1997/1998 crisis. After the 2008 global financial crisis, the central bank applied a more flexible IT as a monetary policy framework. Those various structural reforms produced a high economic growth and gradually promoted Indonesia becoming one of the largest developing countries (Abdurohman & Resosudarmo, 2017).

However, Indonesia's current account has fallen into deficit since late 2011. The maximum target of 2 percent current account deficit to gross domestic product (GDP) ratio was rarely reached. Once the current account deficit exceeded the threshold of 2 percent to GDP, the exchange rate depreciated 12.7 percent on a monthly basis (Nugroho et al., 2014). In the absence of a specific target, the central bank of Indonesia deploys the foreign reserves to intervene in the foreign exchange market. Moreover, the newest law Act No. 4/2023 states that the central bank is responsible not only for currency stabilization but also economic growth. Our question is whether the IT regime is sufficient to cope with the inflation and exchange rate uncertainty in order to achieve a stable economic growth.

This paper explores the role of IT regime on economic performance in developing countries by taking the case in Indonesia. Most studies analyzing economic growth in the IT regime are partial in nature. This study investigates the joint impact of inflation and exchange rate volatility and pioneered in comparing the effect of both variables on growth before and after IT. The paper is structured as follows. After the introduction, Section 2 highlights the review of empirical literature. Methodology and data set are delivered in the preceding section. Then, Section 4 reports the major empirical findings. The last section concludes the paper.

2. Literature review

Economic theories offer various explanations regarding the response of output growth to inflation fluctuations. The aggregate supply-aggregate demand model, Phillips curve, Keynesian school of thought, the quantity theory of money, Monetarism, Neo-classical paradigm, and endogenous growth theories postulate a positive relationship between inflation and output growth (Thanh, 2015). Output and inflation move together in the same direction, suggesting that inflation could adversely affect the output growth.

Most empirical studies regarding the effect of inflation volatility on the output growth support the above theories. Mohd et al. (2013) confirmed that the inflation variability has a significant and adverse impact on economic growth in south east Asian countries. Nene et al. (2022) state that European

countries take advantage of the introduction of IT policy in terms of growth compared to selected African countries. For countries with an unconducive economic environment and institutional conditions, the inflation volatility has no impact on the real GDP growth rate (Kumo, 2015; Stevanovic et al., 2022). However, inflation uncertainty at below a certain threshold value promotes the output growth (Baharumshah et al., 2016).

While the literature on the relationship between inflation volatility and output growth comes to the same conclusion, the link between exchange rate volatility and output growth tends to be divergent. Conceptually, the relationship between the exchange rate and output growth should be similar to the relationship between inflation and output growth. Inflation is a measure of the purchasing power of domestic currency for goods/services, while the exchange rate is the purchasing power of home currency against foreign currencies. The low degree of ERPT and weak purchasing power parity (PPP) causes different impacts of inflation and exchange rate uncertainty on the output growth.

On the one hand, structural economists assert that there is an inverse relationship between the exchange rate and economic growth. Since the input structure of production in developing countries is dominated by imported capital and intermediate goods, home currency depreciation makes the price of imported inputs more expensive and thus adversely affects output growth. On the other hand, the classical paradigm argues that home currency depreciation amplifies the export promotion incentives, enlarges the volume of investment, attracts foreign direct investment inflow, and stimulates import substitution industry (Aman et al., 2017). The increase in exchange rates in countries with low inflation also boost output growth due to the increasing aggregate demand.

The different effects of exchange rate volatility might operate in the different channels. According to Schnabl (2008), there are three channels – international trade, foreign direct investment, and macroeconomic stability – through which exchange rate volatility can promote economic growth. In the first channel, exchange rate uncertainty lowers export flows (Alper, 2017) and improves imports (Senadza & Diaba, 2018). Although the exchange rate is a key element of competitiveness, the impact of exchange rate volatility on export and import is not the same. The impact on imports seems to be smaller (Bostan & Firtescu, 2019).

In the last two channels, the real option theory seems to be appropriate to explain the exchange rate fluctuations. According to the theory, the behavior of investor decisions always considers the macroeconomic conditions (Dixit et al., 1994). The exchange rate unpredictability as an indicator of macroeconomic stability reflects the investment decisions. Firms are encouraged to increase their investment as long as the exchange rates are stable. Unfortunately, empirical studies based on the real option theory produce the mixed results (Glüzmann et al., 2012; Zhao et al., 2014; Habib et al., 2017).

Regardless of the three channels, the exchange rate flexibility serves nicely on output growth through its impact on the adjustment process to surprises (Edwards & Levy-Yeyati, 2005). They argue that exchange rate volatility enables absorbing external shocks due to a better adaptive capacity rather than to avoid the persistent adjustment processes which are economically expensive. Hence, it is not surprising that in the episodes of financial crises economies with a flexible exchange rate enjoy lower output losses (Furceri & Zdzienicka, 2011; Cerra et al., 2013) than economies with a financial openness adoption (Barguellil et al., 2018).

The above theoretical disagreements also hold in the empirical sphere. Jamil et al. (2012) observed that the impact of exchange rate variability on growth is different, but the common currency reduces the

detrimental effect of exchange rate volatility on sectoral output. Rapetti (2020) obtained a positive link between the real exchange rate volatility and output growth in developing economies. In a single country, Aman et al. (2017) discovered that exchange rate uncertainty stimulates output growth in Pakistan. In Bangladesh, Razzaque et al. (2017) demonstrated that in the long run, a 10 percent decrease in the real exchange rate is followed by, on average, a 3.2 percent increase in national output. Studies emphasize the source of uncertainty. The monetary policy surprises under uncertainty significantly affect the stock returns in the US (Benchimol et al., 2023). Benchimol & Ivashchenko (2020) show that US volatility shocks affect the euro area economy. The foreign shocks are significant during the global financial crisis compared with periods of calm. For internal sources of uncertainty, the change in CPI weighting (Benchimol et al., 2022) and terrorist attacks (Benchimol & El-Shagi, 2020) should be considered to forecast inflation and exchange rates. Accordingly, comprehension of monetary policy announcements can reduce negative sentiment (Benchimol et al., 2023).

Specifically for Indonesia, the similar studies are limited. Kusumatrisna et al. (2022) revealed that inflation has a significant adverse impact on growth with a threshold value of 9.59 percent. Utomo & Saadah (2022) compared exchange rate volatility in the managed float and flexible exchange rate systems. They concluded that exchange rate volatility has a significant detrimental impact on growth and the exchange rate regime moderates its effect. Ambaw et al. (2022) noted that the southeast Asia countries, including Indonesia, are more susceptible to exchange rate shocks, implying that the output growth is also vulnerable. However, those studies did not take into account IT regime in their analysis. To sum up, the impact of inflation and exchange rate volatility on the output growth operates with their own channels. In the IT countries, where inflation and exchange rate stabilization is the main goal, it cannot be individually analyzed. A separate analysis could be misleading. A long-term increase in inflation volatility could be triggered by fundamental improvement and a short-term increase in exchange rate volatility might be driven by speculation. Filling this gap, we combine inflation and exchange rate into an integrated approach based on two-stage GARCH (generalized autoregressive conditional heteroscedasticity) estimations. The first model predicts the inflation and exchange rate volatility. The second one accommodates them in the growth convergence mechanism. The integrated behavior of market related output variables provides additional interpretations to policymakers.

3. Research methodology

As inflation is formally the main objective in the IT regime, we begin with the inflation rate and then followed by the exchange rate determinations. In the IT regime, the monetary authorities are supposed to have an ability in predicting future inflation. The actual inflation rate (π) is the relative change in the aggregate domestic price (*PD*). It is also assumed that the actual inflation rate is simply to be performed by the autoregressive process as follows:

$$\pi_t = \Delta\, pd_t = a + b\, pd_{t-1} + \varepsilon_t \tag{1}$$

where the lower-case represents logarithmic form, *a* and *b* are coefficients to be estimated, and ε is a random disturbance term.

The coefficient of *b* is expected to be negative, ranging from 0 (zero) to 1 (unity). The associated parameter shows the persistence of inflation. It can be interpreted as the speed with which inflation goes back to its equilibrium value after a price shock in the previous period. To reiterate, it represents the time it takes to fully dissipate the effect of a one percent rise in price level shock.

Output level (*Q*) and foreign price (*PF*) level in the previous period as control variables are incorporated in the model. The inclusion of *PF* in the model is compatible with the ERPT in respect to import price, instead of exchange rate. In our view, the use of the exchange rate as the regressor in the inflation determination is not suitable. The exchange rate is one of the stabilization goals in the IT regime, not the policy instrument. Moreover, Peon & Brindis (2014) argue that the exchange rate shocks are irrelevant to describe inflation variation.

To characterize the IT regime, the targeted inflation rate (*IT*), dummy variable for IT adoption (*DIT*) consisting of the pre- and post-IT regime, and dummy variable for high inflation rate (*DHI*) are also incorporated. The high inflation is defined as more than 10 percent in annual basis inflation rate.

$$\pi_t = a + b_1\ pd_{t-1} + b_2\ q_{t-1} + b_3\ pf_{t-1} + b_4\ IT_t + b_5\ DIT + b_6\ DHI + \varepsilon_t \qquad (2)$$

The actual exchange rate (*X*) growth is also supposed to be performed by the autoregressive process:

$$\sigma_t = \Delta\, x_t = \alpha + \beta\ x_{t-1} + \epsilon_t \qquad (3)$$

Following the relative PPP hypothesis, the change in exchange rate represents the change in domestic price (*PD*) to foreign price (*FP*) ratio. Another control variable is foreign reserves (*FR*). The change in foreign reserves availability is crucial for the viability of the exchange rate, as it allows the monetary authorities with some space to maintain the PPP in case of shocks (Ebeke & Azangue, 2015). In relation to the IT regime, a dummy variable for IT adoption (*DIT*) and a dummy variable for actual inflation rate outside the inflation range target (*DOT*) are also incorporated. As *DHI* in Equation (2), *DOT* can be seen as an alternative indicator to represent inflation shock.

$$\Delta\, x_t = \alpha + \beta_1\, x_{t-1} + \beta_2\, \Delta\, \frac{pd_t}{pf_t} + \beta_3\, \Delta\, fr_t\ +\ \beta_4\, DIT + \beta_5\, DOT + \epsilon_t \qquad (4)$$

Equations (2) and (4) neglect the complete property of the dependence of the variance of the disturbance term conditional on past volatility, resulting in loss of efficiency. The ARCH model is established to model time-varying conditional variances (Engle, 1982). The ARCH model consists of two equations, first for the mean and second for the conditional variance. The ARCH model solves the problems of heteroscedasticity and volatility clustering by assigning the conditional variance to be linearly dependent on the past behavior of the squared residuals as well as a moving average of past conditional variance:

$$\varepsilon_t^2 = \varphi + \theta\, \Sigma\, \varepsilon_{t-k}^2 \qquad (5)$$

The error variance depends on past volatilities going back a number of periods. For these applications GARCH models are developed (Bollerslev, 1986). The GARCH model depicts conditional variance of a series to depend on a constant, past news about volatility and the past forecast variance. The GARCH(*k*,*l*) model has *k* ARCH terms and *l* GARCH terms:

$$\varepsilon_t^2 = \varphi + \theta \, \Sigma \, \varepsilon_{t-k}^2 + \omega \, \Sigma \, \sigma_{t-1}^2 \quad (6)$$

In many applications the estimates for θ + ω in the GARCH(*1,1*) model approximate to unity, which means that covariance of the model is non-stationary. In that case, the model can be employed only to delineate short-term volatility.

Furthermore, the output growth presumably takes in the form of convergence mechanism (Barro & Sala-i-Martin, 1995):

$$\Delta \, q_t = \alpha + \beta \, q_{t-1} + \mu_t \quad (7)$$

As additional control variable, inflation volatility ($V\pi$) and exchange rate volatility ($V\sigma$) extracted from the conditional variance in equations (2) and (4), respectively, dummy variable for IT adoption (*DIT*), and dummy variable for actual inflation rate outside the target range (*DOT*) are taken into account in the model. The presence of *DOT* is comparable to the threshold inflation rate to output growth model.

$$\Delta \, q_t = \alpha + \beta_1 \, q_{t-1} + \beta_2 \, V\pi_t + \beta_3 \, V\sigma_t + \beta_4 \, DIT + \beta_5 \, DOT + \mu_t \quad (8)$$

Exchange rate in Equation (4) is stated in nominal terms. It can be transformed into real terms by dividing it with respect to the relevant price level. Therefore, the model has the nominal and PPP-based exchange rate. Equation (8) will also be estimated by the GARCH method.

Since growth volatility is our focus, this study needs a long-span and reliable time series data on domestic price, foreign price, exchange rate, foreign reserves, and output. The exchange rate is defined as the price of US Dollar against local currency (Indonesian Rupiah). The domestic price levels refer to the CPI (consumer price index) comprising hundreds of goods and services. The change in industrial production index is utilized as a proxy for real GDP growth.

The foreign price level is represented by the US CPI. All indices are measured in 2012 as a base year (2012 = 100). The foreign exchange reserves are under control of the central bank. Stated in billion US Dollar, they are readily available for any balance of payments financing. The sample periods cover from 2000(M1) to 2022(M12). The observation period extends the pre- and post-IT regime adoption. Large proportion of the monthly monetary data are collected from the central bank of Indonesia. Other economic data are obtained from the Central Board of Statistics and the IMF. The data and variable specification are detailed in Table 1.

Table 1. Data and variable specification.

Variable	Definition	Source
Output (*Q*)	Industrial production index (2012=100)	Central Board of Statistics
Growth (*g*)	Relative change in the industrial production index	Central Board of Statistics
Growth volatility	Variability of output growth	Own estimation, extracted from the model
Exchange rate (*X*)	US Dollar in terms of domestic currency	Central Bank of Indonesia
Exchange rate volatility (V)	Relative change in the exchange rate variability	Own estimation, extracted from the model
Domestic price (*PD*)	Consumer price index (2012=100)	Central Board of Statistics
Inflation volatility (V)	Relative change in the consumer price index variability	Own estimation, extracted from the model
Foreign price (*PF*)	US Consumer price index (2012 = 100)	IMF
Foreign reserves (*FR*)	Foreign assets held by the central bank (in billion US Dollar)	Central Bank of Indonesia
Inflation target rate (*IT*)	Official inflation rate target announced by the government	Central Bank of Indonesia
Inflation targeting regime (*DIT*)	Dummy, before 2005.6 = 0, after = 1	Central Bank of Indonesia
High inflation rate (*DHI*)	Dummy, actual inflation rate > 10% = 1, otherwise = 0	Central Board of Statistics
Actual inflation rate outside the target range (*DOT*)	Dummy, yes = 1, no = 0	Central Board of Statistics

4. Results and discussion

Table 2 summarizes the descriptive statistics of all variables of interest. Each mean value is not far from the respective median value. The minimum and maximum values for each variable are closed to each other. The small negative value of skewness (except exchange rate), which is approaching zero, seems to be adequate to reject the null hypothesis of non-normality. Although all the variables under consideration are platykurtic (kurtosis is less than 3), the Jarque-Bera test confirms that they do not perform the bell-shaped distribution.

Table 2. Descriptive statistic.

	Pd	pf	q	x	fr
Mean	4.50	4.57	4.66	9.30	11.17
Median	4.57	4.59	4.63	9.21	11.47
Maximum	5.04	4.87	5.07	9.70	11.90
Minimum	3.66	4.31	3.89	8.91	10.16
Std. Dev.	0.41	0.14	0.24	0.21	0.59
Skewness	−0.50	−0.07	−0.18	0.29	−0.40
Kurtosis	2.00	2.19	2.18	1.52	1.52
Jarque-Bera	22.98	7.74	9.11	28.99	32.51
Probability	0.00	0.02	0.01	0.00	0.00
Observations	276	276	276	276	276

Source: Own calculation

Among the three indices, domestic price level has the highest variability, indicated by the largest standard deviation (0.41). This means that the domestic price level substantially varies relative to the two others. The higher variability is also found in foreign reserves (0.59). The associated variable tends to be up and down over the observation period, consistent with the behavior of the exchange rate. The positive value of skewness presents that most of the mass of the exchange rate series data occupies the upper-tail distribution. It implies further that the majority of the exchange rate series data is higher than its mean. In other words, the frequency of currency depreciation is more often than appreciation. The synchronous movement between the exchange rate and foreign reserves series data raises a logical question of how closely they are related. Table 3 delivers the correlation matrix between all variable pairs. The change in exchange rate is inversely related to the change in foreign reserves (−0.06). Even the correlation is stronger after the adoption of the IT regime (−0.41). The correlation of domestic inflation-foreign inflation pair (−0.19 and 0.04) is slightly larger than that of domestic inflation-exchange rate pair (−0.03 and −0.02) for the pre- and post-IT adoption, respectively. The weaker correlation after IT adoption is also found in the inflation-output growth pair.

Accordingly, the exchange rate dynamics is more closely associated with the fluctuation of foreign reserves rather than the inflation differentials. Overall, the correlation of most variable pairs is getting weaker after the IT regime adoption. Referring to the related theories, the degree of ERPT seems to decline in the post IT regime adoption as found in many researchers in the empirical literature review section. The relative PPP hypothesis can also be preliminary accepted. Eventually, the stable inflation and exchange rates support the output growth. Those will be re-examined more precisely employing econometric models as specified in the earlier section.

Table 3. Correlation matrix.

	Δ pd	Δ pf	Δ q	Δ x	Δ fr
Δ pd	1.00	0.04	−0.11	−0.02	0.03
Δ pf	−0.19	1.00	0.18	−0.10	0.02
Δ q	−0.21	0.02	1.00	0.06	−0.02
Δ x	−0.03	0.15	−0.06	1.00	−0.41
Δ fr	−0.05	0.11	0.03	−0.06	1.00

Note: the highlighted cells are for the post-IT period Source: own calculation.

Following the standard time series econometric methods, the properties of the underlying data are examined first. The existence of unit roots is evaluated using Augmented Dickey-Fuller (ADF) and ADF with structural breaks. The ADF unit roots test in level series data could be misleading primarily when they are trend-stationary with a structural break. The test is undertaken 4 times for the level and the first-difference data respectively as shown in Table 4. Both tests present that most series data do not have unit roots in level (*I(0)*). After differentiating them, they become stationary (*I(1)*).

The structural break in the domestic inflation rate arose around 2005 when the government increased domestic oil prices (Insukindro & Sahadewo, 2010). The end of the commodity boom era in 2014 depressed Indonesia's export revenues, resulting in the foreign reserves substantially changing. The national output, foreign price, and exchange rate suffered dramatic changes during pandemic Covid-19. In the appearance of structural breaks, the validity of unit roots series data could be accepted at a 1 percent significance level. It means that all variables revert to the mean (as long-run equilibrium) against the shocks. Eventually, they perform the steady-state relationship as suggested by economic theory.

Table 4. ADF unit roots test.

	Level		First-difference		First-diff. with Breakpoint		
	t-stat	Prob.	t-stat	Prob.	t-stat	Prob.	
pd	− 3.6628	0.0052	− 12.6771	0.0000	− 18.1455	<0.01	2005M10
pf	0.6124	0.9899	−10.0401	0.0000	−11.3695	<0.01	2020M04
q	−1.0020	0.7532	−6.3884	0.0000	−8.3116	<0.01	2019M10
x	−1.6122	0.4750	−15.3683	0.0000	−16.0317	<0.01	2020M03
fr	−1.3521	0.6056	−13.8026	0.0000	−14.4746	<0.01	2015M01

Source: own calculation

Table 5 presents the GARCH estimation results of inflation rate. The mean equation without incorporating IT variable (Model 1) provides coefficients that are in line with the theoretical expectations. The output and foreign price level positively affects the inflation rate. A 10 percent increase in both variables stipulates the inflation rate for about 0.06 and 0.23, respectively, on the average. Given the response to the output and foreign price is low, the speed of adjustment to the desired inflation rate is also slow. Only 2 percent of the price level change in the previous month is accommodated in the current inflation rate.

Extending the basic model by incorporating IT regime variables (Model 2) produces higher coefficients. Surprisingly, inflation rate in the post-IT regime on the average tends to be larger, indicated by the positive coefficient of *DIT*. However, the targeted inflation rate and the high inflation rate could reduce the actual inflation rate. In other words, the targeted inflation rate can serve as an anchor to control the current inflation rate. Similarly, the high inflation rate can act as a warning so that the monetary authority takes actions to dampen its movement.

Regardless of the above main economic determinants, there are many other factors influencing the inflation volatility. The pandemic Covid-19, for example, changes the consumption pattern which further alters the CPI weighting (Benchimol et al., 2022). As a result, the estimation results could be contaminated by how the computation of the CPI changed. However, in the Indonesian case, this is less relevant. The change in Indonesia's CPI for calculating inflation starts in 2024. Moreover, we cover the

period 2000–2022. Within the period, changes in the base-year CPI were conducted three times but the inflation data do not show the sharp differences among them.

Table 5. GARCH estimate of inflation rate.

	Model 1		Model 2	
Mean Equation	Coeff.	Prob.	Coeff.	Prob.
C	−0.0419	0.0000	−0.0495	0.0779
pd(−1)	−0.0190	0.0000	−0.0469	0.0000
q(−1)	0.0056	0.0000	0.0231	0.0000
pf(−1)	0.0233	0.0000	0.0342	0.0001
IT	–	–	−0.1604	0.0000
DOT	–	–	0.0123	0.0000
DHI	–	–	−0.0024	0.0023
Variance Equation				
φ	0.0000	0.4554	0.0000	0.0000
θ	−0.0152	0.0000	1.3279	0.0000
ω	1.0141	0.0000	0.0045	0.8952
θ + ω = 1	1.5975	0.2063	3.9530	0.0468
Vπ unit roots test	−1.2195	0.6667	−13.7527	0.0000

Source: own calculation

Regarding the variance equation, the inflation conditional volatility can be explained better by ARCH than the GARCH process. The coefficient of GARCH (ω) is statistically insignificant, particularly in Model (2). However, the χ2-Wald test for (θ = 1) obviously presents that the inflation volatility process returns to the mean value. It seems that the model can be employed not only to explain short-term inflation volatility but also to describe inflation volatility in the longer future.

Figure 1 presents the inflation conditional volatility derived from Model (2). Since the inflation volatility process returns to its mean value, the contour of conditional standard deviation of inflation graph up and down with a solid basic scheme. Hence, the inflation conditional volatility in Model (2) passes unit roots test. The high Indonesia's inflation volatility in certain periods is consistent with the result of unit roots test with structural breaks analysis in the previous paragraphs. As the inflation conditional volatility is stationary, it will be employed to explain the output growth volatility in the preceding sections.

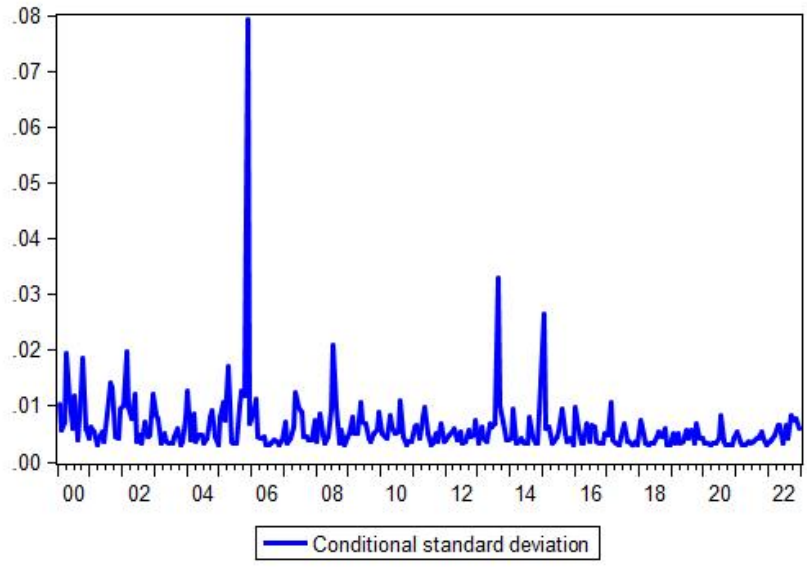


Figure 1. Inflation rate volatility. Source: own calculation.

The GARCH estimation results for nominal and real exchange rate volatility are reported in Table 6. In the nominal term, the growth of the exchange rate is less than the relative price growth. A 1 percent increase in the relative price induces the exchange rate to depreciate for about 0.56 percent on the average, suggesting the presence of weak-PPP form. However, the t-test indicates that the corresponding coefficient statistically equals to or even greater than unity, which confirms the strong-PPP hypothesis. In other words, the growth of the exchange rate is greater than that of the relative price, particularly when the annual inflation rate is greater than 10 percent.

Fortunately, the increase in foreign reserves stock can hamper the exchange rate to depreciate. As noted by Ebeke & Azangue (2015), the foreign reserves availability plays an important role for the monetary authorities to maintain the PPP-based exchange rate credibility. In contrast, the IT regime adoption does not have any effect on the exchange rate volatility. This finding denies the study of Chițu & Quint (2018) for most developing countries, especially when a country has stable foreign reserves stock to intervene in the foreign exchange market. Hence, given the low degree of persistence (0.01 and 0.03), the change of exchange rates tends to be more responsive with respect to economic conditions.

Figure 2 presents the nominal and PPP-based exchange rate conditional volatility. Compared to inflation volatility, it is observed that the graph contours of conditional standard deviation of exchange rate rather up and down. It seems that the IT adoption in Indonesia puts too much focus on stabilizing the home currency value thus leading to mildly ignored stabilizing its external value, eventually resulting in the high exchange rates unpredictability, as found by Kuncoro (2020).

Similar to inflation volatility, there are many other economic factors determining exchange rate uncertainty. Benchimol & El-Shagi (2020), for example, point out that decision-makers should consider terrorist attacks. Terrorism as a mostly endogenously driven form of political uncertainty and assess the forecasting performance of market-based and professional inflation and exchange rate forecasts. Accordingly, expert forecasts are better than market-based forecasts particularly during periods of

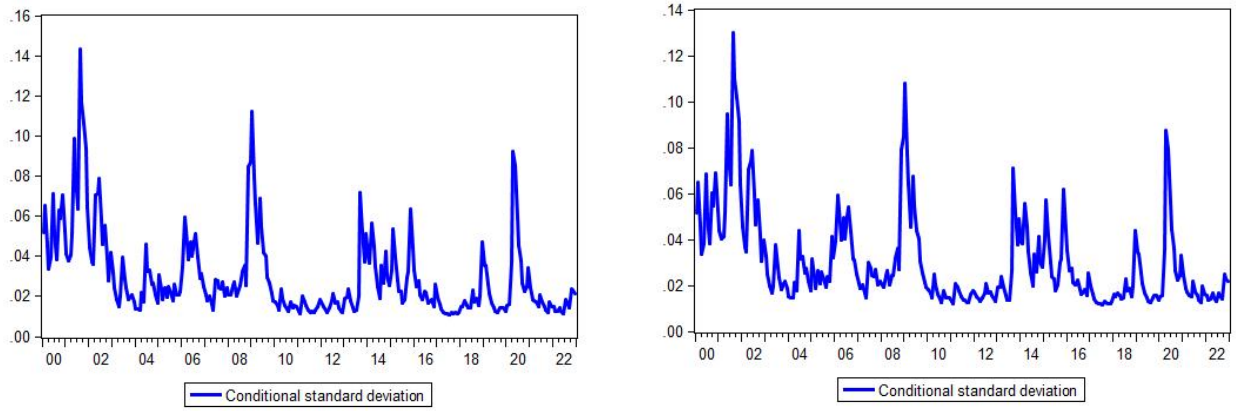
terrorism. Indonesia was in the case. Terrorist attacks occurred in the early 2000s. During that period, exchange rate showed sharp differences compared to the subsequent periods, resulting in the exchange rate professional forecast is more valid.

Table 6. GARCH estimate of exchange rate.

	Nominal Exchange Rate		PPP-Based Exchange Rate	
Mean Equation	Coeff.	Prob.	Coeff.	Prob.
C	0.1016	0.0460	0.3235	0.0001
x(−1)	−0.0107	0.0557	−0.0343	0.0001
Δ (pf/pd)	0.5632	0.0000	–	–
Δ fr	−0.2779	0.0000	−0.2966	0.0000
DIT	0.0023	0.4921	−0.0031	0.4417
DHI	0.0235	0.0000	0.0108	0.0000
Variance Equation				
φ	0.0001	0.0066	0.0001	0.0234
θ	0.6470	0.0000	0.4431	0.0000
ω	0.4585	0.0000	0.5808	0.0000
θ + ω = 1	1.2673	0.2603	0.1127	0.7371
Vσ unit roots test	−5.2501	0.0000	−4.5996	0.0002

Source: own calculation

Furthermore, both the nominal and PPP-based exchange rate volatility process return to the respective mean value (have unit roots). The high Indonesia's exchange rate volatility in certain observation periods (primarily in the pandemic Covid-19 in 2020) is consistent with the result of ADF unit roots test with structural breaks analysis. Since each exchange rate conditional volatility is typically stationary, it will be used later to explain the output growth volatility in the next sections.



Nominal Exchange Rate PPP-Based Exchange

Figure 2. Exchange rate volatility. Rate Source: own calculation.

The preceding section focuses on the empirical results of the output growth volatility. Table 7 delivers the estimation results of Equation (8) from the GARCH regressions. There is evidence that output growth on average is slightly higher (*p*-value 0.06) in the post-IT regime. Thus, the output growth convergence hypothesis is proven. The lower initial output level tends to grow slower than the higher one so that the "catch-up effect" mechanism holds. The speed of adjustment for initial output level to converge (−0,03) is similar from other developing countries as found by Barro & Xala-i-Martin (1995).

It is also notable that the inflation volatility is indeed harmful for economic growth, indicated by the negative sign in the two specification models, respectively. A 1 basis point increase in the conditional standard deviation of inflation volatility tends to retard output growth for about 1.4–1.7 percent on the average. Moreover, the threshold of 9.59 percent proposed by Kusumatrisna et al. (2022) is confirmed, indicated by the significance of *DOT* slope. Therefore, the central bank of Indonesia that puts too much focus on stabilizing the home currency value seems to be justified in relation to the growth impact.

The similar result is found in the context of exchange rate volatility. Both the nominal ($V\sigma 1$) and PPP-based exchange rate volatility ($V\sigma 2$) hurt economic growth, confirming Utomo & Saadah (2022). The effect of PPP-based exchange rate volatility on the output growth (−0.47) is greater than that of nominal exchange rate volatility (−0.36). Those size impacts are close to the findings of Razzaque et al. (2017). Regardless of the types of nominal and real, the effect of conditional standard deviation of exchange rate volatility is less than that of inflation volatility. At this point, allowing the exchange rate to be volatile (to attract short-term capital inflow) remains tolerable since its impact on the output growth is not as much as inflation rate volatility.

The lagged dependent variable in the two estimation models is significant, indicating that our estimated output growth rate models are well-specified. Given the relatively low partial adjustment mechanism, the output growth tends to be more persistent to adjust to any fluctuations in the short-term. This implies that the habit slowly changes over time. Since the output growth rate volatility in the variance equation is predictable ($\theta + \omega = 1$), the economic authorities could initiate the targeting of foreign currency movements, current account imbalances, and foreign reserves stock in addition to the objectives of stabilizing the output growth.

Accordingly, nominal GDP are better suited for stabilization goals. In light of big supply shocks and terms of trade shocks, the full impact of adverse supply shocks is felt as lost real GDP (Bhandari & Frankel, 2017). Nominal GDP targeting automatically accommodates such shocks, while retaining the advantage of anchoring expectations. Under annual IT, nominal GDP targeting would dominate other regimes to achieve objectives of output and price stability.

Furthermore, it is necessary to check the constancy of the growth rate function. The constancy of parameters is required for an effective monetary policy. Therefore, it has to be tested whether the estimated growth rate equation is stable or has shifted over time. As observed in Figures 1 and 2, there are some outlier observations of the inflation instability and exchange rate volatility, resulting in the coefficient estimates not precisely reflecting the underlying statistical relationship. Moreover, the mean equation in the GARCH estimators is susceptible to the existence of observations that lie outside the norm of the regression equation of interest.

Table 7. GARCH estimate of output growth.

	Model 1		Model 2	
Mean Equation	Coeff.	Prob.	Coeff.	Prob.
C	0.1386	0.0009	0.1366	0.0009
q(−1)	−0.0356	0.0001	−0.0346	0.0002
Vπ	−1.6791	0.0000	−1.4352	0.0000
Vσ1	−0.3586	0.0000	–	–
Vσ2	–	–	−0.4726	0.0000
DIT	0.0554	0.0000	0.0541	0.0000
DOT	−0.0149	0.0017	−0.0151	0.0011
Variance Equation				
φ	0.0005	0.0004	0.0005	0.0002
θ	0.6936	0.0000	0.7133	0.0000
ω	0.3300	0.0006	0.3125	0.0014
θ + ω = 1	0.0400	0.8414	0.0452	0.8317

Source: own calculation

As a robustness test, Equation (8), by including a dummy variable for the global financial crisis (2007–2009) and pandemic Covid-19 (2020–2022), is re-estimated[1]. The inclusion of the two dummy variables in the models is suitable to represent exogenous shocks. The results show that those additional variables do not alter our conclusion. They do not change the magnitude and significance of our estimators, indicating the earlier models encompass the current models. However, comparing the pre- and post-IT regime, the latter results remain supporting the presence of lesser impacts of exchange rate volatility relative to inflation volatility on the output growth.

Ideally, the impact of internal (inflation) and external (exchange rate) uncertainty on the economic growth volatility is estimated using a non-linear approach (Benchimol & Ivashchenko, 2021). The negative surprises and positive surprises exert different strengths of the effect. However, both inflation and exchange volatility in this study are extracted from the GARCH model. The GARCH model is based on the conditional standard deviation which does not differentiate between negative and positive values. The nonlinearity is captured by the significance of *DIT*, *DOT*, and *DHI*, respectively. According to Kuncoro & Fafurida (2023), the GARCH method is comparable to the asymmetric and nonlinear model.

5. Conclusions

Low and stable inflation and exchange rates are the main objectives of IT monetary policy. The internal and external stabilities are prerequisite to stimulate economic growth. Accordingly, the adoption of the IT regime in emerging markets is believed to stimulate output growth. However, theoretical considerations and empirical findings regarding the impact of IT adoption on economic growth provide conflicting results. We investigate the impact of inflation instability and exchange rates volatility on economic growth in emerging markets with IT.

[1] The result can be obtained from the author on request.

Taking the case of Indonesia over the period 2000(1)–2020(12), we found that the inflation rate in the post-IT adoption on the average is higher relative to that in the pre-IT adoption even though the targeted inflation can reduce the actual inflation rates. Interestingly, there is a little different exchange rate instability in the two regime periods. Therefore, the effect of IT regime adoption on the output growth is slightly marginal. However, the two-stage GARCH estimation models show that both inflation and exchange rate unpredictability hurt economic growth. The effect of inflation uncertainty is greater than that of exchange rate instability and the effect of PPP-based exchange rate unpredictability is higher than that of nominal exchange rate instability.

Given the fact that Indonesia, as many other emerging IT countries, has high exchange rate uncertainty relative to other developing countries, our findings suggest that economic authorities should strengthen their commitment to achieve the inflation target. Complicating the policy implementation on the inflation and exchange rate stability leads to a destabilizing effect. Eventually, the sharper focus on the inflation rate stability might elude Indonesia's monetary authority to impose twin goals of inflation and exchange rate stability to stimulate economic growth in the frame of IT regime. The present study is limited to the nominal and real exchange rates instability. In the future, similar research studies on output growth need to be carried out to explore the exchange rate misalignment instability, a longer span time series data analysis thus will be required.

6. Policy implications

Financial uncertainty has a significant role in shaping the influence of monetary policy on the economic sector. Those findings suggest a better management of inflation and exchange rate volatility. The central banks, for example, could manage volatility using communication. The textual uncertainty is correlated with the volatility of the domestic financial market. Therefore, a clear monetary policy announcement could reduce the negative sentiment, which is aligned with economic fluctuations.

Another important policy implication is related to the change in monetary policy transmission to the markets under high volatility and uncertainty. Economic agents commonly react more aggressively to monetary policy surprises during periods of high uncertainty rather than low uncertainty. The different response influences the transmission of positive and negative monetary policy surprises to economic growth.

Eventually, the nominal income targeting is more suitable in the case of Indonesia in particular and developing countries in general. Considering the central bank's loss functions, nominal income level targeting is superior relative to real income targeting. Our findings suggest that Taylor-type rule is more appropriate to achieve the central bank's objectives for each type of period (stable, crisis, and recovery).

Use of AI tools declaration

The author declares that they have not used Artificial Intelligence (AI) tools in the creation of this article.

Acknowledgment

This work was financially supported by the Faculty of Economics, State University of Jakarta, Indonesia.

Conflict of interest

The authors declare no conflicts of interest in this paper.

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