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Abstract

This study investigates historical inflation persistence in India under three distinct regimes: monetary targeting, multiple indicator, and inflation targeting (IT). Previous stud- ies for India relied heavily on mean-based estimation techniques, which are biased when inflation has a skewed distribution and do not account for the tail behavior of inflation. As a result, we use a quantile-based estimation approach to test for persistence in in- flation, gaining insights into the stationary properties of various parts of the distribution rather than just the mean. Our regime-specific results point to asymmetric inflation be- havior, with varying persistence depending on the inflation-affecting shock. We observe high inflation persistence during the multiple indicator regime, which declines with the implementation of IT, particularly in the Pre-COVID sample. Our findings show that imple- menting IT has been beneficial in reducing inflation persistence in developing countries such as India. However, the IT regime was not very effective during COVID-19 in reduc- ing inflation persistence. Therefore, given the intransient nature of inflation in emerging economies, central banks should exercise more caution and patience.

Keywords: Inflation Persistence; Monetary Regime; Quantile regression

JEL Code: C21, E31, E52

A historical perspective on India's inflation persistence: a quantile analysis

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1. Introduction

Countries worldwide are undergoing significant shifts in their approach to monetary policy, notably through the implementation of inflation targeting (IT) (de Haan et al., 2007). While this strategy has proven effective in helping advanced economies control inflation and reduce inflation persistence (Batini and Nelson, 2001; Beechey and Österholm, 2009), its impact on emerging economies has been inconsistent (Oliveira et al., 2014). With the increased adoption of IT regimes globally, the role of a monetary policy regime in influencing inflation dynamics is still under evaluation. For an emerging economy like India, a relatively new entrant to the IT monetary regime, it is crucial to examine how inflation persistence has behaved historically under its various monetary regimes. Moreover, this analysis captures the effect of shocks of varying intensity on inflation persistence in developing countries like India, which typically experience higher inflation rates than many developed economies.

Inflation persistence is an important factor in understanding inflation dynamics because it refers to how quickly inflation returns to its intended value or equilibrium after a shock. Increased inflation persistence causes inflation to take longer to reach equilibrium, increasing price instability. Consequently, the costs associated with stabilizing inflation rises, resulting in greater welfare loss. Inflation persistence also measures the path central banks take when faced with the trade-off between inflation and output stability. According to Beechey and Österholm (2009), inflation persistence reflects the central bank's willingness to stabilize inflation relative to output. It also reflects the central bank's credibility and how well expectations are anchored. Well-anchored expectations reduce inflation persistence in IT regimes (Levin and Piger, 2004). Consequently, the evolution of inflation persistence under various monetary regimes sheds light on the central bank's changing preferences for stabilization.

This study provides a historical analysis of inflation persistence in India across three distinct regimes: monetary targeting (June 1986 - April 1998), multiple indicator (May 1998 - July 2016), and inflation targeting (August 2016 - April 2023). Additionally, within the IT regime, we examine a sub-sample of the Pre-COVID period (August 2016 - February 2020) to account for the impact of COVID-19 on inflation. Existing literature offers several approaches to understanding inflation persistence.[1] Several studies in India have also investigated this topic, including Khundrakpam (2008), Dua and Goel (2021b), and John (2015). According to Khundrakpam (2008), the multiple indicator regime showed lower inflation persistence than the monetary targeting regime. In contrast, Dua and Goel (2021b) found that the RBI's multiple indicator approach resulted in higher inflation persistence from 2009 to 2013. However, John (2015) observed decline in inflation persistence under the same regime between 2010 and 2012. With a focus on comparing the behavior of inflation under various monetary regimes, our paper offers a 'historical' account of inflation persistence in India covering the period from 1986 to the most recent data available until 2023, which the existing studies do not capture.

We use the quantile regression approach to study the historical account of inflation persistence in India. The existing literature for India (Khundrakpam, 2008; Dua and Goel, 2021b; John, 2015) has predominantly relied on mean-based estimation methods to evaluate inflation persistence, which can be biased in the presence of asymmetry.[2] The distribution of inflation often deviates from the normal distribution, exhibiting skewed or asymmetric characteristics around its mean, as indicated by Kottaridi et al. (2009) and Muduli

[1] Fuhrer (2010) presents a brief review of existing literature.

[2] Mean-based estimation or the method of least squares, involves minimizing the square of residuals. However, the estimates of the conditional mean can be strongly influenced by outliers, resulting in biased estimation.

and Shekhar (2023) for the case of India. To account for the non-normal behavior of Indian inflation and capture the tail behavior, we explore the quantile regression approach, following methodologies used in studies such as Wolters and Tillmann (2015), Anguyo et al. (2020), and Phiri et al. (2018). The approach will allow us to gain insights into the stationary properties of various parts of the distribution rather than just the mean. Moreover, for our preliminary analysis, we use rolling regression, as it allows us to trace how inflation persistence has changed with time. Furthermore, we examine the distribution of inflation across different sectors to guide monetary policy effectively (Roger, 2000).

We calculate inflation by considering year-on-year percentage changes in two widely used price indices: the Consumer Price Index for Industrial Workers (CPI-IW) and the Wholesale Price Index (WPI). [3] We further consider both aggregated and disaggregated measures of inflation. We consider the following disaggregates for CPI-IW: food, housing, fuel, clothing, tobacco, miscellaneous, and the core. We consider the following WPI disaggregates: primary, fuel, manufacturing, and the core.

Our rolling regression results indicate significant variability in inflation persistence as measured by CPI-IW and WPI inflation during the multiple indicator regime. This variability is largely driven by fluctuations in food and fuel inflation, highlighting the role of supply shocks in affecting inflation persistence. These findings are similar to those of Dua and Goel (2021b). Moreover, we observe a declining trend in inflation persistence with the adoption of the IT regime, but it quickly reverses with the emergence of the COVID-19 pandemic.

Additionally, our findings from the quantile unit root tests reveal global non-stationarity for WPI inflation and most of its disaggregates during the multiple indicator regime, indi-

[3] For WPI, the data is available only for the multiple indicator regime and the IT regime, while for CPI-IW, the data is available for all the three regimes.

cating that these series do not revert to their mean after experiencing a shock.[4] During the IT regime, particularly in the Pre-COVID period, the WPI inflation and most of its disaggregates exhibited global stationarity, with occasional periods of local non-stationarity. This suggests that shocks to inflation have temporary effects, inflation eventually will revert to its mean in the long run. However, the time taken by inflation to return to its mean varies depending on local inflation dynamics, and it will be longer for quantiles exhibiting local non-stationarity.[5]

For CPI-IW, inflation was globally stationary during all the regimes, although local non-stationarity was observed for some quantiles. However, for CPI-IW disaggregates, inflation was globally stationary during the monetary targeting regime and the Pre-COVID IT regime. However, some of the disaggregates were globally non-stationary for both the multiple indicator regime and the entire IT regime. For instance, fuel inflation was globally non-stationary during the multiple indicator regime, while core and food inflation were globally non-stationary during the entire IT regime which includes the COVID-19 period, however they displayed global stationarity in the Pre-COVID IT regime. To summarize, the Pre-COVID IT regime has performed the best in terms of reducing inflation persistence in India, followed by the monetary targeting regime.

In general, we find non-stationary behavior only when inflation is affected by severe shocks; otherwise, it is stationary. Moreover, our study corroborates earlier research by Behera and Patra (2022), illustrating a reduction in inflation persistence after the adoption of IT in India. However, COVID-19 has raised concerns about the effectiveness of IT regime.

[4] Global non-stationarity means the presence of a unit root conditional on the entire distribution. If a series has a unit root or is non-stationary, it indicates that the series will not revert to its mean after being impacted by a shock, suggesting that shocks to the level of the series have permanent effects.

[5] In the quantile approach, when inflation lies in the upper quantile compared to the past data, it is assumed to be affected by a positive shock and vice versa for the case of negative shock.

The structure of the paper is as follows: Section 2 presents a brief literature review of inflation persistence. Section 3 discusses the empirical methodology used in the analysis. Section 4 summarizes and interprets the empirical findings. Finally, Section 4 concludes the paper with policy implications.

2. Review of literature

A considerable amount of literature exists on inflation persistence; most of it explores inflation dynamics in the context of developed countries. However, in the last two decades, the focus has shifted to emerging economies, which has brought a new perspective to the inflation persistence literature.

2.1. Monetary regime and inflation persistence

Existing literature suggests a critical link between the monetary regime and inflation persistence. Erceg and Levin (2003) provided a theoretical framework to establish this link. They demonstrated that inflation persistence is not an intrinsic characteristic of the economy but rather arises from agents' perceptions of the central bank's commitment to achieving the inflation target. Agents cannot directly observe the components underlying the inflation due to its variability. As a result, they forecast future inflation levels and incorporate these into their current wage and price contract decisions.

Overall, the shifts in monetary policy regime have a substantial impact on inflation persistence; the following section reviews some of the literature around it in the context of developed countries and emerging economies:

Developed economies

Barsky (1987) found that before World War I, during the gold standard era, inflation in the USA exhibited no persistence. From 1914 to 1959, however, there was moderate inflation persistence. Post-1960s, inflation showed significant persistence, highlighting how different monetary regimes influence inflation dynamics. Additionally, Batini and Nelson (2001) demonstrated a sharp decline in inflation persistence under the Volcker-Greenspan monetary policy regime in the USA, and a similar decrease was observed in the UK after adopting explicit IT in 1992. For OECD countries, Bratsiotis et al. (2015) noted a significant decline in inflation persistence after the adoption of IT regimes.

Given the substantial literature suggesting the role of monetary policy in affecting inflation persistence in developed economies, now we explore literature around emerging economies to explore similar dynamics and the influence of monetary regimes on inflation persistence.

Emerging economies

Calvo and Mishkin (2002) identified several factors distinguishing emerging market economies (EMEs) from advanced economies, including the quality of fiscal and financial institutions, the credibility of monetary institutions, currency substitution, and vulnerability to sudden stops in capital inflows, which are more pronounced in EMEs (Fraga et al., 2003). Chiquiar et al. (2010) found that Mexico's adoption of an IT regime in 2000 shifted inflation from a non-stationary to a stationary process. Similarly, in the Asia-Pacific region, inflation persistence declined with the adoption of IT regimes, enhancing price stability, though the speed of decline varied across countries (Gerlach and Tillmann, 2012). In contrast, Oliveira et al. (2014) noted that inflation persistence varied among EMEs, decreasing in Brazil and Peru but increasing in Bolivia, Turkey, and Mexico.

Having explored the literature on emerging economies, our focus now shifts to India, the central theme of our research.

Inflation and its measurement in India

In India, various measures have been used in the existing literature to assess the general price level that is used to calculate inflation, specifically (i) WPI and (ii) CPI-IW. Moreover, we consider their disaggregates. Before the recent introduction of the new Consumer Price Index (CPI) measures, WPI and CPI-IW were predominantly utilized in policy circles and academic discussions as the primary measures for calculating inflation in India; therefore, we look at these two measures. [6]

The WPI and CPI-IW exhibit significant disparities in their weighting diagrams, leading to variations in the importance assigned to specific commodity groups. The CPI-IW places a substantial emphasis on food, with a weight of 57%, making it highly sensitive to fluctuations in food prices. In contrast, the WPI assigns a combined weight of only 27% to food articles and food products. Additionally, the WPI gives a higher weight to the fuel group (14.23%) compared to the CPI-IW (6.28%), indicating that international crude oil price movements impact the WPI more significantly. Furthermore, the CPI-IW includes services in its miscellaneous group, covering transport, education, and healthcare, whereas the WPI does not account for services. These differences contribute to the disparities in inflation rates between the two series, as the CPI-IW captures price changes in the services sector, which the WPI does not.

These discrepancies in weighting and coverage underscore the differing sensitivities and composition of the two indices, emphasizing the need for careful interpretation and

[6] With the introduction of the new CPI measures, the Reserve Bank of India (RBI) now relies on them as the principal gauge to measure inflation in the country. We are not using CPI inflation data, since the data for CPI is from 2011 onwards and covers mainly the IT regime.

comparison of inflation rates derived from the WPI and CPI-IW series. [7]

Indian inflation story

This section provides a brief history of inflation in India across the three monetary regimes considered. Thornton (2006) found that, between 1958 and 2005, the average inflation was generally low. However, there were periods of increased volatility, primarily driven by drought conditions affecting agricultural production and international energy crises. In 1985, India adopted a monetary targeting regime with feedback based on evidence of a stable demand for money function. Recommended by a committee chaired by Dr. Sukhamoy Chakravarty, the aim was to maintain inflation within acceptable bounds while promoting output growth. Instead of fixed targets for money supply growth, a range subject to mid-year adjustments was used (Dua, 2020). In the early 1990s, India experienced another surge in inflation due to rising primary product prices and a balance of payments crisis. In response, the Reserve Bank of India (RBI) adopted the multiple indicator approach in 1998. This approach considered various macroeconomic and financial factors when crafting monetary policy, rather than relying solely on a single M3 aggregate. This strategy provided flexibility to respond to changes in domestic and international economic conditions, though growth in broad money (M3) remained a significant indicator of monetary policy.

During the 2000s, inflation persistence became less frequent, indicating that the economy had become more resilient to inflationary pressures and had benefited from favorable global conditions. However, inflation rose during 2008-2010 due to a rise in food prices (Nair and Eapen, 2012). Between 2010 and 2013, Indian inflation remained persistently high, driven by rising food prices caused by increased demand rather than supply con-

[7] Please see Appendix Table C.2 and Table C.3 for updates in weights of sub-categories of WPI and CPI-IW , respectively.

straints, as agricultural production and productivity growth did not decline during this period (Nair, 2013). The persistence of inflation during this period posed a perplexing question (Goyal, 2015). Inflation was widespread across various categories, initially starting with food inflation and extending to non-food manufactured products (Patra et al., 2014). However, Darbha and Patel (2012) suggests that inflation was not solely due to food and energy prices but rather due to the persistence in core sector inflation. Overall, inflation remained high until 2014.

Based on the recommendation of the RBI's Report of the Expert Committee to Revise and Strengthen the Monetary Policy Framework (Patel et al., 2014), India, in August 2016, formally adopted flexible IT as its monetary policy approach. The Central Government announced in the Official Gazette dated August 5, 2016, that the inflation target for the Consumer Price Index (CPI) would be set at 4%, with a tolerance band of ±2%, valid for the period from August 5, 2016, to March 31, 2021.[8] After adopting the IT regime, inflation was contained within the stipulated band until the COVID-19 crisis, which saw a rise in inflation, even crossing the upper limit of 6%.

Inflation persistence in the context of India

Since her independence, India has experienced several episodes of persistent inflation. Patra et al. (2014) suggests that the period from 1947 till 2013-14 had ten episodes of inflation persistence, with July 1986–Dec 1995 being the most persistent period.

Khundrakpam (2008), for the period between 1982:q4 to 2008:q3, observed that India has a lower inflation persistence level compared to other advanced economies. He observed that the inflation persistence for 'Food' and 'Fuel' was lower than that of man-

[8] In March 2021, the government retained the target at 4% headline CPI inflation for April 2021-March 2026.

ufacturing and its components. Overall, during the multiple indicator approach, inflation persistence was lower compared to the monetary targeting regime.[9] Moreover it was observed that the persistence is disaggregates was not consistently lower than the aggregates. Further, John (2015) after analyzing monthly WPI data from April 2004 to June 2012 found that inflation persistence increased between 2004 and 2009. Notably, the food group, particularly protein prices, experienced a rise in persistence, suggesting demand-side factors could be influencing this increase. However, he found that inflation persistence declined during 2010-2012, coinciding with a tight monetary policy regime.

For the period from 1996:q4 to 2017:q2, Dua and Goel (2021a) found inflation to be persistent for both WPI and CPI-IW, especially from January 2010 to January 2013. They suggested that supply-side factors such as fuel and food prices played a significant role in increasing inflation persistence. Furthermore, Behera and Patra (2022) found a decline in inflation persistence from 2014 to 2019. They attributed this decline in inflation persistence to policies implemented during flexible IT regime, which helped anchor inflation expectations.

Existing literature indicates that inflation persistence in India has evolved over time, influenced significantly by monetary policy. However, much of the literature has primarily utilized conditional mean estimation methods, which may not accurately capture asymmetric inflation behavior and could potentially lead to biased estimations. Given the importance of tail behavior in understanding the impact of various shocks, our analysis adopts conditional quantile estimation techniques. Unlike mean-based regression methods, these techniques model the entire conditional distribution of the response variable, offering insights beyond just the conditional mean. This approach is particularly valuable when

[9] The sample size considered in Khundrakpam (2008) is till 2008 only which does not comprise full sample of multiple indicator regime.

critical information lies in the distribution tails, providing a more nuanced understanding of inflation persistence dynamics.

3. Empirical methodology:

We use rolling regression for our preliminary analysis of how persistence has evolved over time in different regimes.[10] Furthermore, in order to account for non-normal inflation behaviour, we use quantile approach to inflation persistence which allows for asymmetric dynamics and quantile-specific unit roots.

3.1. Quantile estimation

Quantile regression allows researchers to study the relationship between covariates and dependent variables not only at the center but throughout the distribution. Compared to ordinary least square (OLS) estimation, it enables the estimation of the marginal effect along different quantiles of the dependent variable distribution, which helps in examining the asymmetric behavior and nonlinear effects of the independent variables on the dependent variable.

For a random variable Y with a cumulative distribution function (CDF), F(y)=$\Pr(Y \le y)$, the qth ($q \in (0,1)$) quantile of Y is:

$$Q_Y(q) = F_Y^{-1}(q) = inf\{y : F(y) \ge q\}, \quad (1)$$

So, the quantile function is the inverse of the CDF. Empirically, a qth quantile, y_q, is the y value that splits the data into proportions q below and 1-q above $F(y_q) = q$ and $y_q = F^{-1}(q)$.

[10] Details for rolling regression is discussed in Appendix B.

Consider a regression given by: $y_i = x_i\beta + e_i$. While OLS regression minimizes the square of the error terms $\sum_i e_i^2$, median-based regression minimizes the absolute value of the error term $\sum_i |e_i|$. Quantile regression generalizes the median regression, that is, it minimizes a sum that gives asymmetric penalties (1-q)$|e_i|$ for over-prediction and q$|ei|$ for under-prediction.

Formally, the quantile regression estimator of coefficients β for the quantile q minimizes the following objective function (i.e., the check function)

$$Q(\beta_q) = \sum_{i:y_i \geq x_i\beta}^{N} q|y_i - x_i\beta_q| + \sum_{i:y_i < x_i\beta}^{N} (1-q)|y_i - x_i\beta_q|, \tag{2}$$

We measure inflation persistence as the sum of the autoregressive process of inflation. [11] Following Koenker and Xiao (2004, 2006), Wolters and Tillmann (2015) and Gaglianone et al. (2018) for a specific quantile (τ), the AR(p) process can be written as a QAR(p) process, which is given as:

$$q_\tau(\pi_t|\pi_{t-1}\ldots,\pi_{t-p}) = \alpha(\tau) + \rho(\tau)\pi_{t-1} + \Sigma_{k=1}^{p-1}\gamma_k(\tau)\Delta\pi_{t-k} \tag{3}$$

In Equation 3, the τ-th quantile, denoted as $q_\tau(\pi_t|\pi_{t-1}\ldots,\pi_{t-p})$, represents a value such that the probability of the conditional inflation rate being less than $q_\tau(\pi_t|\pi_{t-1}\ldots,\pi_{t-p})$ is τ, while the probability of it being greater than $q_\tau(\pi_t|\pi_{t-1}\ldots,\pi_{t-p})$ is 1–τ.

In the context of quantile regression applied to the above equation for calculating inflation persistence, the estimates of $\rho(\tau)$ indicate how much inflation tends to persist at the quantile τ given past inflation values $\pi_{t-1},\ldots,\pi_{t-p}$. This approach allows for different degrees of persistence based on the size and impact of inflation shocks. When inflation

[11] This is the reduced-form approach to measuring inflation persistence, so it is difficult to account for the structural sources of inflation persistence. Therefore, we do not make any claim about structural sources of inflation persistence.

significantly surpasses recent inflation levels, it suggests a substantial positive shock to inflation, positioning it above the mean based on previous observations within the upper conditional quantiles (Wolters and Tillmann, 2015). Conversely, if inflation is lower compared to prior periods, it implies a negative shock to inflation, placing it below the mean within the lower conditional quantiles, considering past observations. Therefore, persistence at, say, $\tau = 0.7$ quantile doesn't necessarily signify persistence at high inflation levels. Instead, it indicates persistence when inflation experiences a substantial positive deviation from its conditional mean.

3.2. Quantile unit root test

We follow the methodology suggested by Koenker and Xiao (2004) to test for a unit root, and the test runs in two stages. Initially, we test for unit root behavior in specific quantiles, and then we use a Kolmogorov-Smirnov (KS) type test to check for the presence of a unit root across the entire quantile distribution. It is plausible that inflation shows characteristics of a unit root process within certain quantiles while demonstrating mean reversion across other quantiles, ultimately leading to an overall global mean reversion.

In order to test for the null- H_0: $\rho_\tau = 1$, for selected quantiles $\tau \in (0, 1)$, we use the t-ratio test proposed by Koenker and Xiao (2004) which is given by

$$t_n(\tau) = \frac{f(\widehat{F^{-1}(\tau)})(\pi'_{-1} M_z \pi_{-1})^{1/2}(\hat{\rho}(\tau) - 1)}{\sqrt{\tau}(1 - \tau)}, \tag{4}$$

where $f(\widehat{F^{-1}(\tau)})$ denotes consistent estimator of $f(F^{-1}(\tau))$, while f and F indicate the probability density function and CDF of the residual ϵ_t in Equation B.2, π_{-1} is the vector of lagged inflation whereas M$_z$ is the projection matrix onto the space diagonal to Z = (1, $\Delta\pi_{t-1}$, $\Delta\pi_{t-2}$, $\Delta\pi_{t-1}$,...,$\Delta\pi_{t-p+1}$).

Now, to analyze the persistence of inflation over a large range of quantiles, Koenker and Xiao (2004) suggests using the Quantile Kolmogorov-Smirnov (QKS) test. It is an extension of a KS-type test and is given by:

$$QKS = sup|t_n(\tau)| \tag{5}$$

where $t_n(\tau)$ is the t-statistics in Equation(4). The paper Koenker and Xiao (2004) showed that the limiting distribution of $t_n(\tau)$ can be written as:

$$t_n(\tau) = \delta\left(\int_0^1 \underline{W}_1^2(r)dr\right)^{-1/2} \int_0^1 \underline{W}_1(r)dW_1(r) + \sqrt{1-\delta^2}N(0,1), \tag{6}$$

where $\underline{W}_1(r) = W_1(r) - \int_0^1 \underline{W}_1(s)ds$ and $W_1(r)$ is standard Brownian motion. So, the limiting distribution of $t_n(\tau)$ shown in Equation 6 is a mixture of a Dickey-Fuller component and a standard normal component, with weights given by the parameter δ which is equal to

$$\delta = \frac{\sigma_{\epsilon\psi}}{\sigma_\epsilon\sqrt{\tau(1-\tau)}} \tag{7}$$

where σ_ϵ is the long run variance of ϵ_t and $\sigma_{\epsilon\psi}$ is the long run covariance ϵ_t and $\psi_\tau(\epsilon_{t\tau})$. [12] The critical values of $t_n(\tau)$ for values of δ^2 is given in Hansen (1995).

[12]Note: $\psi_\tau(x) = \tau - \mathrm{I}(x < 0)$ while $\epsilon_{t\tau}$ is the residual of Equation 3.

4. Results

This section presents results for regime-wise univariate analysis of inflation considering WPI and its disaggregates between January 1995 and May 2023.[13] The disaggregates of WPI inflation (WPII) includes, primary inflation (WPII-primary), fuel inflation (WPII-fuel), and manufacturing inflation (WPII-manufacturing), calculated using the respective indices. Additionally, we examine inflation calculated using CPI-IW and its components, focusing on the period from June 1986 to May 2023. The disaggregates of CPI-IW inflation (CPII-IW) are food inflation (CPII-IW-food), housing inflation (CPII-IW-housing), fuel inflation (CPII-IW-fuel), cloth inflation (CPII-IW-cloth), tobacco inflation (CPII-IW-tobacco), and miscellaneous inflation (CPII-IW-misc), each calculated using their respective indices. Following Goyal (2022), we also consider core measures of inflation for both CPI-IW (CPII-IW-core) and WPI (WPII-core), which usually represent inflation arising due to demand shocks. For the CPII-IW-core, we removed volatile items like food and fuel from CPI-IW, while the WPII-core comprises non-food manufactured products.[14]

4.1. Rolling regression results

Our preliminary analysis examines inflation persistence considering 5 years of mean-based rolling regressions. Moreover, to mitigate potential estimation biases, we use the bootstrap method to generate confidence bands. The results for WPII, WPII-core, and its disaggregates are presented in Figure 1 while the results for CPII-IW, its core and disaggregates are presented in Figure 2.

[13] Inflation for the full sample and regime-wise analysis is calculated using year-on-year percentage change, i.e., $Inflation_t = \frac{(P_t - P_{t-12})}{P_{t-12}} \times 100$, where P_t is the monthly price index.

[14] All measures of inflation, both at aggregate and disaggregate levels, were calculated after seasonally adjusting the respective price indices using Census X-13 seasonal adjustment.

If the absolute value of inflation persistence (ρ), is 1 it suggests that the inflation rate follows a unit root process, behaving like a random walk. This means there is infinite persistence, with shocks to the inflation rate having a permanent impact and not fading over time. Conversely, when ρ is less than 1, the inflation rate exhibits mean-reverting behavior after a shock, indicating a stationary process. In such a process, shocks to the inflation rate eventually diminish, and the rate returns to its long-term equilibrium.

As evident from Figure 1, WPII persistence was more variable during multiple indicator regime than during IT regime. This also holds true for WPII-primary , WPII-manufacturing and WPII-fuel. For instance, Panel c of Figure 1 highlights significant variability in WPII-primary persistence, with an initial decline in the early 2000s, a spike around 2004, and stability around 0.8 until 2015 due to rising food prices. However, WPII-core persistence remained consistently high i.e. ρ is close to 1 throughout both the regimes.

The analysis of CPII-IW persistence, shown in Figure 2, reveals large fluctuations during monetary targeting and multiple indicator regimes, however both inflation persistence magnitude and variability declined during the IT regime . The majority of its subcategories exhibited similar behaviour. As shown in Panel c to f of Figure 2, the multiple indicator regime saw large fluctuations in persistence for CPII-IW-food, CPII-IW-fuel, and CPII-IW-tobacco, while the adoption of IT regime saw a decline in persistence across all sub-categories. The CPII-IW-core behavior as shown in Panel b of Figure 2 showed increased variability in inflation persistence during monetary targeting regime, which stabilised during the multiple-indicator and IT regimes. However, during this period, the magnitude of inflation persistence remained high. For example, the value of CPII-IW-core persistence remained high at around 0.9 until 2001, then fell until 2006, then rebounded to 0.9 in 2007, and remained there until 2015. Under the IT regime, CPII-IW-core persistence initially declined until 2017, then surged to a value of about 0.95.

During the IT period, we observe a significant decline in both CPII-IW and WPII inflation persistence based on the results of rolling regressions. This aligns with the findings by Mohan and Ray (2019) and Behera and Patra (2022), who noted a substantial reduction in Indian inflation during this regime. Furthermore, we investigate inflation persistence behavior using quantile autoregression, which allows us to examine the impact of varying shocks on inflation across different quantiles of the distribution.

4.2. Quantile approach results

Given the skewed distribution of inflation and its disaggregates as shown in Table A.1 and Table A.2, we further investigate the presence of persistence using the quantile unit root tests. The results for quantile-based analysis, considering both the t-ratio test and QKS test, are presented in Table 1 for WPII, WPII-core, and WPII disaggregates, and in Table 2 for CPII-IW, CPII-IW-core, and CPII-IW disaggregates. The t-ratio test examines the presence of unit roots in specific conditional quantiles, while the QKS test examines the presence of unit roots in the entire conditional distribution of the sample.

During the multiple indicator regime, we found that WPII exhibited high persistence at both aggregate and disaggregate levels, as indicated by both the QKS test and the t-ratio test.[15] Notably, the high inflation persistence observed in WPII-core during this regime aligns with the findings of Ball et al. (2016), who attributed it to the slow adjustment of inflation expectations. However, as shown in Table 1, the persistence of WPII significantly reduced during the IT regime, especially in the Pre-COVID IT period,[16] which demonstrated global mean reversion at both aggregate and disaggregate levels, as indicated by a QKS test value of 0. The lack of inflation persistence behavior in WPII-manufacturing

[15] Refer to the respective rows under the column header "Multiple Indicator Regime" of Table 1 for WPII, WPII-core, WPII-fuel, WPII-primary, and WPII-manufacturing.

[16] Refer to the column header "Pre-COVID IT Regime" of Table 1.

and WPII-fuel before COVID-19, coupled with its presence afterward, suggests that supply chain disruptions during the pandemic may have influenced inflation dynamics, consistent with the findings of Patnaik (2022). Focusing on a specific quantile-based unit root test within the IT regime, we observed that WPII and some of its disaggregates exhibit asymmetric behavior, where persistence across quantiles varies depending on whether the shock is positive or negative.[17] For example, WPII-core and WPII-primary, tends to be persistent primarily for positive deviations from the conditional mean.

We proceed with an inflation analysis considering different monetary regimes for CPII-IW, its core, and disaggregates. For the monetary targeting regime, as shown in Table 2 under the column head "Monetary targeting Regime," the QKS test suggests that inflation is mean-reverting over the whole conditional distribution for CPII-IW, CPII-IW-core, and sub-categories of CPII-IW. Now, focusing on the t-ratio test for the monetary targeting regime, according to Table 2, both CPI-IW and its disaggregates show asymmetric behaviour, with inflation being persistent mainly for positive shocks to inflation.

Subsequently, during the multiple indicator regime, as indicated in Table 2, CPII-IW inflation displayed non-stationary shocks across different conditional quantiles but remained stationary at a global level, suggesting inflation reverted to its mean in the long run. Further analysis of CPII-IW-core and CPII-IW disaggregates reveals that CPII-IW core, CPII-IW-misc, and CPII-IW-food exhibited behavior similar to that of the CPII-IW aggregate. However, sub-categories such as CPII-IW-fuel, CPII-IW-cloth, CPII-IW-housing, and CPII-IW-tobacco showed non-mean reverting behavior across the entire conditional distribution level. CPII-IW inflation remained more persistent during this regime than in the previous monetary regime. This result is consistent with findings from Bhatt and Kishor (2016),

[17] Refer to the respective rows under the column head "IT Regime" of Table 1 for WPII, WPII-core, WPII-fuel, WPII-primary, and WPII-manufacturing.

who also observed high inflation persistence across multiple indicator regime.

During the most recent regime, specifically the IT regime spanning from 2016 to 2023, our analysis indicates that CPII-IW is globally stationary.[18] In contrast, CPII-IW-core exhibits a pattern of global non-stationarity. Among its sub-categories, CPII-IW-food, CPII-IW-cloth, and CPII-IW-housing exhibit consistent non-mean reverting behavior across the entire conditional distribution. The quantile unit root tests further corroborates the presence of unit roots across most of the quantiles for CPII-IW and its disaggregates, suggesting increased inflation persistence, possibly due to the impact of COVID-19.

Turning our attention to the Pre-COVID sample within the IT regime, an analysis of the data reveals a significant reduction in the range of specific quantiles where the presence of a unit root is observed. [19] This reduction is evident when compared to the full sample of the IT regime, as well as the monetary targeting and multiple indicator regimes. In the analysis based on specific conditional quantiles, inflation exhibits mean-reverting behavior in most cases, with the exception of extreme deviations within the respective sub-categories.

Overall, our results suggest asymmetry in India's inflation behavior across regimes. Our findings align with Çiçek and Akar (2013) and Gaglianone et al. (2018), who observed mean-reverting inflation across the entire quantile conditional distribution and presence of unit roots in specific quantiles, however we also find instances of global non-stationarity. The decline in inflation persistence upon adopting the IT regime corroborates findings by Çiçek and Akar (2013) and Valera et al. (2017). Additionally, the Pre-COVID IT regime shows the least persistence in inflation, consistent with Behera and Patra (2022) and Raj

[18] Refer Column “IT Regime” of Table 2.

[19] Refer to QKS under Column head Pre-COVID IT Regime of Table 2 considering respective rows for CPII-IW and its sub-categories.

et al. (2020), who noted a decline in persistence since the adoption of IT. Our results contradict Azad and Das (2013), who questioned the effectiveness of IT regimes in developing countries. We find that adopting IT has reduced inflation persistence in India, as evidenced by both CPII-IW and WPII measures of inflation.

5. Conclusions

Maintaining price stability has become a crucial goal for central banks across various economic landscapes, whether in advanced or developing nations. Consequently, exploring the enduring nature of inflationary trends is essential, particularly in countries newly embracing IT policies. With increased persistence in inflation worldwide after COVID-19, emerging economies are bearing the brunt of it. This study delves into inflation persistence in India, utilizing quantile regression methods. This approach accounts for potential disparities that might emerge after varying magnitudes of shocks. Moreover, this framework better suits variables displaying heavy-tailed characteristics, as indicated by the initial findings from the summary statistics.

Overall, our regime-wise analysis reveals the presence of unit roots across entire conditional distributions, particularly among the disaggregates. We observe inflation to be non-stationary during multiple indicator regimes compared to the IT regime. Furthermore, our findings indicate asymmetry in inflation behavior, particularly when influenced by substantial shocks. Hence, central banks must exercise caution when managing extreme economic shocks.

Table 1: WPII and its disaggregates inflation persistence

Variables	Multiple indicator regime		IT regime		Pre-COVID IT regime	
Test	QKS	t-ratio	QKS	t-ratio	QKS	t-ratio
WPII	1	all quantile	0	0.3-0.75	0	0.2-0.65
WPII-core	1	all quantile	0	0.4-0.7	0	0.2-0.7; 0.8
WPII-primary	0	0.6-0.8	0	0.35; 0.55-0.65;0.8	0	0.2; 0.55-0.8
WPII-fuel	1	0.2-0.6; 0.75:0.8	1	0.2-0.4; 0.5-0.8	0	0.25-0.8
WPII-manufacturing	1	all quantile	1	all quantile	0	0.25-0.45

Notes:
QKS: Unit root test considering the whole distribution
t-ratio: Unit root test across every quantile

- QKS column: If 0, stationary, and if 1, non-stationary
- t-ratio column: Quantiles across which there is a unit root (non-stationary)
- "-" represents interval

Table 2: CPII-IW and its disaggregates persistence

Variables	Monetary targeting regime		Multiple indicator regime		IT regime		Pre-COVID IT regime	
Test	QKS	t-ratio	QKS	t-ratio	QKS	t-ratio	QKS	t-ratio
CPII-IW	0.00	0.6-0.8;	0.00	0.25-0.8	0.00	0.35-0.75	0.00	0.3-0.6; 0.8
CPII-IW-core	0.00	0.75-0.8;	0.00	0.45-0.8	1.00	0.2-0.75	0.00	0.2;0.8
CPII-IW-food	0.00	0.25-0.3;0.5-0.8	0.00	0.35-0.8	1.00	0.2-0.6;0.7-0.8	0.00	0.2-0.5;0.8
CPII-IW-fuel	0.00	0.2-0.4;0.65-0.8	1.00	0.2-0.3; 0.5-0.8	0.00	0.2-0.8	0.00	0.2;0.8
CPII-IW-housing	0.00	0.2-0.35; 0.65-0.8	1.00	all quantile	1.00	all quantile	0.00	0.2;0.8
CPII-IW-tobacco	0.00	0.4-0.8	1.00	0.25-0.8	0.00	0.2-0.5;0.65-0.8	0.00	0.2;0.8
CPII-IW-misc	0.00	0.2;0.75-0.8	0.00	0.35-0.8	0.00	0.25-0.75	0.00	0.80
CPII-IW-cloth	0.00	0.35-0.8	1.00	all quantile	1.00	all quantile	0.00	0.2;0.3-0.5

Notes:
QKS: Unit root test considering the whole distribution
t-ratio: Unit root test across every quantile

- QKS column: If 0, stationary, and if 1, non-stationary
- t-ratio column: Quantiles across which there is a unit root (non-stationary)
- "-" represents interval

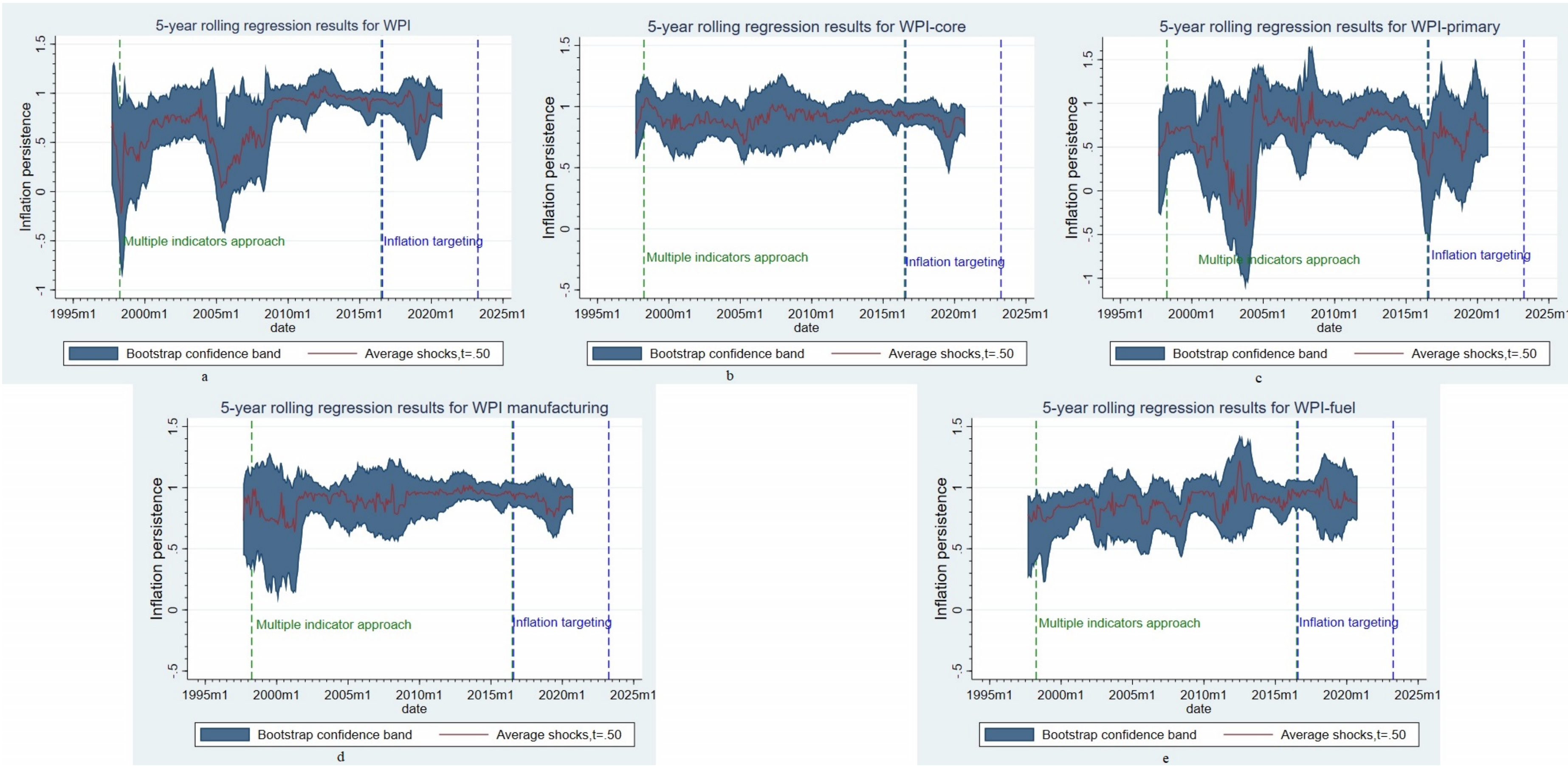

Figure 1: WPI and its disaggregates inflation persistence

Notes: The graph shows WPI and its disaggregates considering five years rolling estimates of ρ at the conditional mean (solid line) together with 95 percent bootstrapped confidence band (gray areas) for the period between 1996 to 2023.

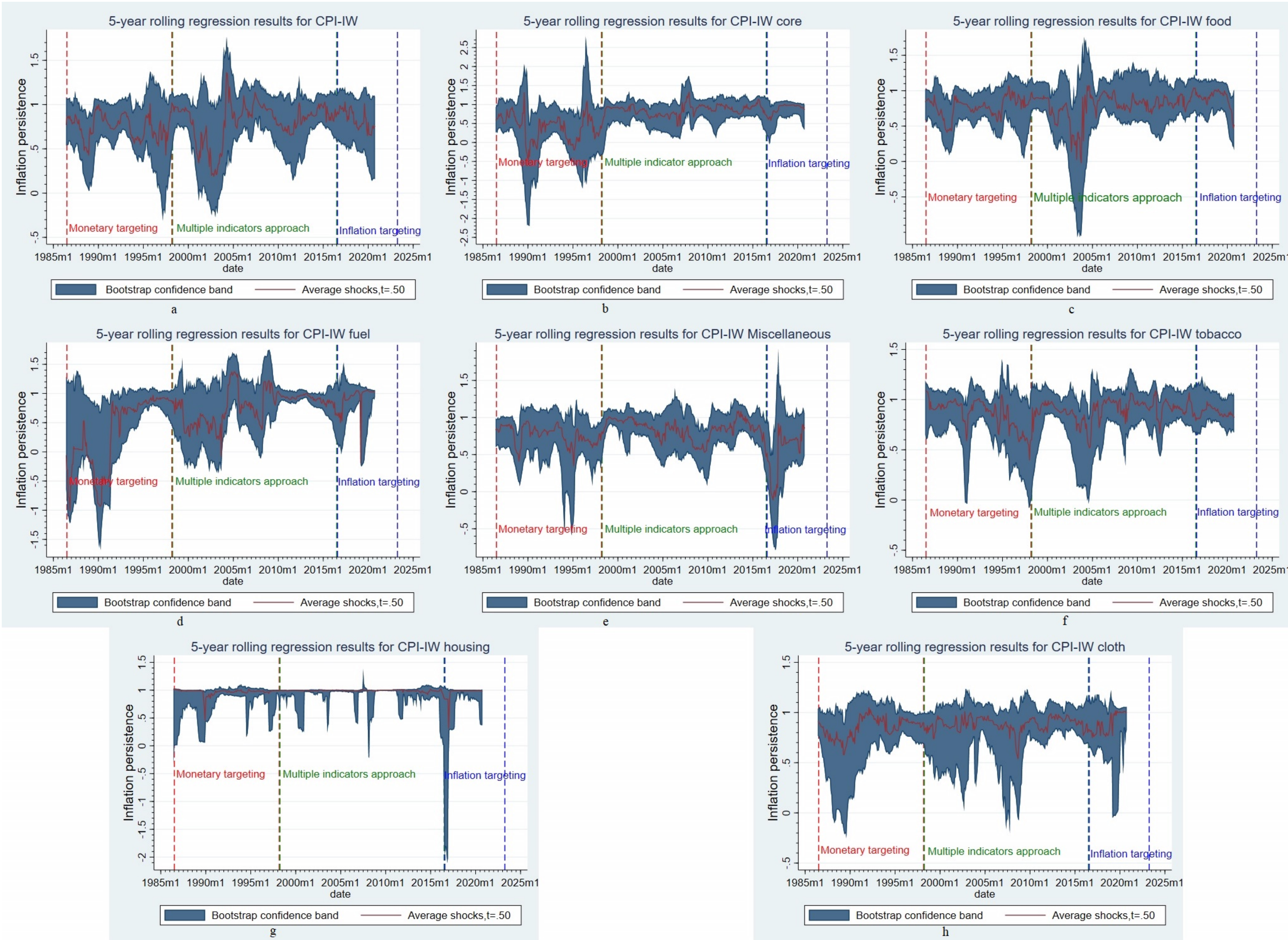

Figure 2: CPI-IW and its disaggregates inflation persistence

Notes: The graph shows inflation persistence of CPI-IW, and its disaggregates considering five years rolling estimates of ρ at the conditional mean (solid line) together with 95 percent bootstrapped confidence band (gray areas) for the period between 1986 to 2020.

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Appendices

Appendix A

Table A.1: WPI and its disaggregates Normality test

Shapiro-Wilk W test for normality

Variable	Obs	W	V	z	Prob>z
WPII	337	0.98364	3.864	3.191	0.00071
WPII-core	339	0.98105	4.5	3.551	0.00019
WPII-fuel	337	0.96236	8.891	5.158	0
WPII-manufacturing	337	0.98068	4.564	3.584	0.00017
WPII-primary	337	0.96794	7.574	4.779	0

Skewness and kurtosis tests for normality

				Joint test	
Variable	Obs	Pr(skewness)	Pr(kurtosis)	Adj chi2(2)	Prob>chi2
WPII	337	0.7581	0.0138	6.08	0.0478
WPII-core	339	0.0021	0.4947	9.12	0.0105
WPII-fuel	337	0.2648	0.0004	12.2	0.0022
WPII-manufacturing	337	0.0009	0.1529	11.62	0.003
WPII-primary	337	0	0.912	15.58	0.0004

Table A.2: CPI-IW and its disaggregates normality test

Shapiro-Wilk W test for normality

Variable	Obs	W	V	z	Prob>z
CPII-IW	629	0.88895	45.963	9.296	0
CPII-IW-core	629	0.87442	51.977	9.594	0
CPII-IW-food	629	0.94289	23.636	7.681	0
CPII-IW-fuel	629	0.66441	138.898	11.981	0
CPII-IW-housing	629	0.74161	106.945	11.346	0
CPII-IW-misc	629	0.85393	60.456	9.961	0
CPII-IW-cloth	629	0.86278	56.795	9.809	0
CPII-IW-tobacco	629	0.97806	9.081	5.358	0

Skewness and kurtosis tests for normality

				Joint test	
Variable	Obs	Pr(skewness)	Pr(kurtosis)	Adj chi2(2)	Prob>chi2
CPII-IW	629	0	0	111.91	0
CPII-IW-core	629	0	0	204.25	0
CPII-IW-food	629	0.0006	0	48.3	0
CPII-IW-fuel	629	0	0	352.06	0
CPII-IW-housing	629	0	0	234.25	0
CPII-IW-misc	629	0	0	215.54	0
CPII-IW-cloth	629	0.9247	0	70.87	0
CPII-IW-tobacco	629	0	0.5495	20.6	0

Appendix B

Rolling regression

For our preliminary analysis, we use rolling regression considering a 5-year rolling period while using the bootstrap method to generate a confidence band. Our rolling regression analysis estimates an AR(p) model, as shown below.

Let π_t measure inflation, α an intercept term, and ϵ_t be a serially uncorrelated error term. Consider an AR(p) process given by:

$$\pi_t = \alpha + \Sigma_{k=1}^{p}\beta_k \pi_{t-k} + \epsilon_t \tag{B.1}$$

where inflation persistence $(\rho) = \Sigma_{k=1}^{p}\beta_k$. Equation B.1 can be re-written in difference terms as follows:

$$\pi_t = \alpha + \rho\pi_{t-1} + \Sigma_{k=1}^{p-1}\gamma_k \Delta\pi_{t-k} + \epsilon_t \tag{B.2}$$

where $\Delta\pi_t = \pi_t - \pi_{t-1}$. The parameter ρ in Equation B.2 holds significant implications for the nature of the inflation process.[20] When the absolute value of ρ, denoted as $|\rho|$, equals 1 (i.e., $|\rho| = 1$), it indicates that the inflation rate possesses a unit root, resulting in a random walk process. This implies infinite persistence, as shocks to the inflation rate have a lasting impact and do not dissipate over time. Conversely, if $|\rho|$ is less than 1 (i.e., $|\rho| < 1$), the inflation rate exhibits mean-reverting characteristics following a shock, indicating a stationary process. In a stationary process, shocks to the inflation rate eventually fade away, and the inflation rate returns to its long-term equilibrium level. The magnitude of ρ thus provides valuable information about the persistence and stationarity of the inflation process. The estimates of ρ in Equation B.2 can be obtained from least square estima-

[20] Following Wolters and Tillmann (2015), we consider lag length p=12 for both CPI-IW and WPI inflation aggregates and its disaggregates which is sufficient to eliminate serial correlation.

tions. However, the least square estimation suffers from a bias as ρ approaches unity; therefore, we also estimate the confidence band of ρ following Hansen (1999).

Further, we use the quantile estimation method to test for the presence of unit roots.

Appendix C

Table C.1: Number of different products under different base years for WPI

	Major Groups/Groups	1981-82	1993-94	2004-05	2011-12
	All Commodities	447	435	676	697
1	**Primary Articles**	93	98	102	117
1.1	Food Articles	44	54	55	76
1.2	Non Food Articles	28	25	29	28
1.3	Minerals	21	19	18	11
1.4	Crude Petroleum & Natural Gas			1	2
2	**Fuel and Power**	20	19	19	16
2.1	Coal		4	4	5
2.2	Mineral Oils		10	10	10
2.3	Electricity		5	5	1
3	**Manufactured Products**	334	318	555	564
3.1	Food Products	35	41	57	60
3.2	Beverages	7	11	15	7
3.3	Tobacco Products	NA	NA	NA	3
3.4	Textiles	27	29	55	25
3.5	Wearing Apparel	NA	NA	NA	8
3.6	Leather and related Products	3	1	13	11
3.7	Wood and Products of Wood and Cork	2	2	10	10
3.8	Paper and Paper Products	11	11	18	20
3.9	Printing and Reproduction of Recorded Media	NA	NA	NA	7
3.10	Chemical and Chemical Products	77	69	107	77
3.11	Pharmaceuticals, Medicinal Chemical and Botanical Products	NA	NA	NA	23
3.12	Rubber and Plastics Products	13	15	45	38
3.13	Other Non-Metallic Mineral Products	22	9	26	26
3.14	Basic Metals	57	53	69	41
3.15	Fabricated Metal Products, Except Machinery and Equipment	NA	NA	NA	27
3.16	Computer, Electronic and Optical Products	NA	NA	NA	18
3.17	Electrical Equipment	NA	NA	NA	48
3.18	Machinery and Equipment	44	56	107	61

Table C.1: Continued

	Major Groups/Groups	1981-82	1993-94	2004-05	2011-12
3.19	Motor Vehicles, trailers and Semi-Trailers	22	21	33	24
3.20	Other Transport Equipment	NA	NA	NA	11
3.21	Furniture	NA	NA	NA	6
3.22	Other Manufacturing	NA	NA	NA	13

Source: Office of the Economic Advisor, Ministry of Commerce

Table C.2: Weights of different products under different base years for WPI

	Major Groups/Groups	1970-71	1981-82	1993-94	2004-05	2011-12
	All Commodities	100	100	100	100	100
1	**Primary Articles**	41.67	32.3	22.03	20.118	22.618
1.1	Food Articles	29.8	17.39	15.4	14.337	15.256
1.2	Non Food Articles	10.62	10.08	6.138	4.258	4.119
1.3	Minerals	1.247	4.823	0.485	0.623	0.833
1.4	Crude Petroleum & Natural Gas				0.9	2.41
2	**Fuel and Power**	8.459	10.66	14.23	14.91	13.152
2.1	Coal		1.256	1.753	2.094	2.138
2.2	Mineral Oils		6.666	6.987	9.364	7.95
2.3	Electricity		2.741	5.484	3.452	3.064
3	**Manufactured Products**	49.87	57.04	63.75	64.972	64.23
3.1	Food Products	12.32	10.14	11.54	9.974	9.122
3.2	Beverages	2.708	2.149	1.339	1.762	0.909
3.3	Tobacco Products					0.514
3.4	Textiles	11.03	11.55	9.8	7.326	4.881
3.5	Wearing Apparel					0.814
3.6	Leather and Related Products	0.385	1.018	1.019	0.835	0.535
3.7	Wood and Products of Wood and Cork	0.174	1.198	0.173	0.587	0.772
3.8	Paper and Paper Products	0.851	1.988	2.044	2.034	1.113
3.9	Printing and Reproduction of Recorded Media					0.676
3.10	Chemical and Chemical Products	5.548	7.355	11.93	12.018	6.465
3.11	Pharmaceuticals, Medicinal Chemical and Botanical Products					1.993
3.12	Rubber and Plastics Products	1.207	1.592	2.388	2.987	2.299
3.13	Other Non-Metallic Mineral Products				2.556	3.202
3.14	Basic Metals	5.974	7.632	8.342	10.748	9.646
3.15	Fabricated Metal Products, Except Machinery and Equipment					3.155
3.16	Computer, Electronic and Optical Products					2.009

Table C.2: Continued

	Major Groups/Groups	1970-71	1981-82	1993-94	2004-05	2011-12
3.17	Electrical Equipment					2.93
3.18	Machinery and Equipment	5.045	6.268	8.363	8.931	4.789
3.19	Motor Vehicles, trailers and Semi-Trailers	1.673	2.705	4.295	5.213	4.969
3.20	Other Transport Equipment					1.648
3.21	Furniture					0.727
3.22	Other Manufacturing	0.546	0.972	0	0	1.064

Source: Office of the Economic Advisor, Ministry of Commerce

Table C.3: CPI-IW disaggregates weights

Groups	Labour Bureau		
	1982	2001	2016
I-A Food & Beverages (Food Group)*	57	46.2	39.17
I-B Pan, Supari, tobacco & Intoxicants	3.15	2.27	2.07
II. Fuel & Light	6.28	6.43	5.5
III. Housing	8.67	15.27	16.87
IV. Clothing & Footwear (Clothing,Bedding& Footwear)*	8.54	6.57	6.08
V. Miscellaneous	16.36	23.26	30.31