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Inflation trends in Asia: implications for central banks

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Abstract

Trend inflation estimates for 12 of the largest Asian economies over 1995-2018 offer important insights on inflation dynamics and inflation expectations. The disinflationary shocks that hit the region since 2014 were partly transitory, but their effects have been different depending on the behaviour of trend inflation in each country. Countries with relatively high inflation (India, Philippines, Indonesia) benefited, and some were impacted very mildly (China, Taiwan, Hong Kong SAR, Malaysia). Among countries with inflation below target, in those with trend inflation low but constant (Australia, New Zealand) low inflation maybe lasting, but temporary, while those in which trend inflation has declined (South Korea, Thailand) risk low inflation to become entrenched and a de-anchoring of expectations. This diverse international evidence could offer important lessons for monetary policy worldwide.

JEL codes: C11, C32, E31, F41

Keywords: trend inflation, survey inflation expectations, Asian economies, state space model, stochastic volatility

Non-technical summary

Uncertainty about inflation dynamics has resurfaced recently in many countries. Since the Global Financial Crisis (GFC) there have been some puzzling episodes of both missing disinflation and missing inflation along the economic recovery, and many Advanced (AEs) but also some Emerging Economies (EMs) have experienced protracted periods of below-target inflation. Against this background, improving inflation analysis to allow central banks to better distinguish transitory from permanent influences driving inflation away from that target is particularly important at the current juncture, when inflation targeting regimes in place in most AEs and EMs have been questioned after the GFC, and the adoption of additional objectives for central banks (e.g. financial stability considerations) has triggered an on-going debate on the optimal degree of flexibility in inflation targeting.

This paper investigates developments in headline inflation and inflation expectations through the lens of trend inflation. Specifically, we apply a Beveridge-Nelson decomposition to observed inflation rates, by estimating a trend, or permanent component, and a transitory, or (cyclical) inflation gap. Methodologically, we employ an extension of the unobserved component and stochastic volatility (UCSV) model of Stock and Watson (2007). Following Chan, Clark and Koop (2018), our empirical framework therefore exploits the forward-looking information content of long-term survey measures of inflation expectations, but, importantly, allows for the potential level of trend inflation and the reported level of survey inflation expectations to differ over time. We can therefore assess the information content of survey expectations for the conduct of monetary policy in each country and the presence of potential episodes of de-anchoring of inflation expectations when they take place.

We estimate trend inflation for 12 of the largest Asian economies, six AEs (Australia, Hong Kong, Japan, Korea, New Zealand, and Taiwan) and six EMs (China, Indonesia, India, Malaysia, Philippines, and Thailand) between1995 and 2018. Asia has been the world's most dynamic economic area over the last few decades. Yet, inflation research for the region arguably lags somewhat behind that available for trade, exchange rates and capital flows or growth. This paper contributes to fill that void and shows that trend inflation estimation offers important insights for central banks regardless of differences in inflation objectives and monetary policy regimes.

Our main findings are as follows. We show that trend inflation estimation provides valuable information for monetary policy beyond the traditional core inflation measures. A decomposition of Asian inflation into trend and transitory components shows that the bulk of the decline in inflation in the region over the last two decades is explained by lower trend inflation. More recently, the disinflationary shocks that hit the region since 2014 were partly transitory, but their effects have been different depending on the behaviour of trend inflation in each country. Countries with relatively high inflation (India, Philippines, Indonesia) benefited, and some were impacted very mildly (China, Taiwan, Hong Kong SAR, Malaysia). Among countries with inflation below target, in those with trend inflation low but constant (Australia, New Zealand) low inflation maybe lasting, but temporary, while those in which trend inflation has declined (South Korea, Thailand) risk low inflation to become entrenched and a de-anchoring of expectations. This diverse international evidence could offer important lessons for monetary policy worldwide.

1 Introduction

Uncertainty about inflation dynamics has resurfaced since the Global Financial Crisis (GFC). Both the missing disinflation in the aftermath of the GFC and the missing inflation after the recovery have triggered controversy about inflation behaviour (e.g. IMF, 2013, 2016). In particular, since the GFC a large number of Advanced (AEs) but also some Emerging Economies (EMs) have experienced protracted periods of below-target inflation. Indeed, while fluctuations in oil prices have driven shifts in headline inflation rates in most economies, core inflation rates have been rather muted worldwide.

The inflation puzzles that emerged in the post-GFC years point to a need to improve inflation analysis to allow for a successful implementation of monetary policy. In particular, whenever inflation departs from the chosen inflation target, the optimal monetary policy response needs to be based on a comprehensive analysis of the reasons driving inflation away from that target and how persistent those forces are. This is particularly important at the current juncture, when inflation targeting regimes in place in most AEs and EMs have been questioned after the GFC, and the adoption of additional objectives for central banks (e.g. financial stability considerations) has triggered an on-going debate on the optimal degree of flexibility in inflation targeting.

Long-term inflation expectations have also become a crucial element for modern monetary policy. The monetary transmission mechanism is most effective when inflation expectations are strongly anchored, and the expectations channel has become an effective mechanism to achieve monetary policy objectives. Indeed, references to private sector's long-term inflation expectations have become increasingly common in central bank's communication (see, e.g., Draghi, 2014, 2019, Powell 2017, 2019) and specialized press and market commentary (e.g. The Economist, 2014, 2017; Financial Times, 2016, 2019).

This paper investigates developments in headline inflation and inflation expectations through the lens of trend inflation. Specifically, we apply a Beveridge-Nelson decomposition to observed inflation rates, and estimate a trend, or permanent component, and a transitory, or (cyclical) inflation gap. In this context, trend inflation reflects the most likely inflation rate to be observed once the transitory influences on inflation die away, and can therefore be interpreted as the optimal conditional long-term inflation forecast. The central bank's capacity to distinguish between permanent and transitory influences in inflation rates is crucial when setting the appropriate monetary policy stance. Misinterpreting lasting inflationary pressures by merely transitory moves in inflation may set inflation on a course —in either direction—that may become much more difficult to revert in the future, may turn out costly in terms of economic activity, and may harm central bank credibility. Gauging underlying inflationary pressures nonetheless remains challenging, and we show that trend inflation estimation provides valuable information for monetary policy beyond the traditional core inflation measures.

Trend inflation is estimated using an extension of the unobserved component and stochastic volatility (UCSV) model of Stock and Watson (2007). In particular, to account for the important role of inflation expectations in inflation dynamics, survey measures are incorporated into the estimation of trend inflation following Chan, Clark and Koop (2018). Our empirical framework therefore exploits the forward-looking information content of long-term survey measures of inflation expectations, but, importantly, allows for the potential level of trend inflation and the reported level of survey inflation expectations to differ over time. We can therefore assess the information content of survey expectations for the conduct of monetary policy in each country and the presence of potential episodes of de-anchoring of inflation expectations when they take place.

The experiences of Asian economies with trend inflation offer important insights for central banks in the region and worldwide. Asia has been the world's most dynamic economic area over the last few decades. Yet, inflation research for the region arguably lags somewhat behind that available for trade, exchange rates and capital flows or growth. This paper contributes to fill that void. We estimate trend inflation for 12 of the largest Asian economies, six AEs (Australia, Hong Kong, Japan, Korea, New Zealand, and Taiwan) and six EMs (China, Indonesia, India, Malaysia, Philippines, and Thailand) over the period 1995-2018. Most Asian central banks have undertaken significant improvements in their monetary policy frameworks over the last two decades, in some cases as a response to the Asian Financial Crisis (AFC), in other cases as part of their remarkable economic development. While differences across monetary policy regimes persist, the improvements in monetary policy frameworks helped the region weather relatively well the GFC. Asian economies, with the exception of Japan, had not been generally affected by low inflation until recently, but, particularly since 2014, inflation has also been persistently below target in many countries in the region despite quite a robust growth, which make Asia a very interesting region for the study of potential changes in inflation dynamics. This paper shows that trend inflation estimation offers important insights for central banks regardless of differences in inflation objectives and monetary policy regimes. Our country sample comprises some advanced economies with a sound reputation as inflation targeters (e.g. Australia, New Zealand), countries that have struggled with low inflation for long (e.g. Japan) or in more recent years (e.g. South Korea, Thailand), or emerging economies still afflicted by relatively high inflation (e.g. India).

Our main findings are as follows. First, a decomposition of Asian inflation into trend and transitory components shows that the bulk of the decline in inflation in the region over the last two decades is explained by lower trend inflation. Interestingly, both AEs and EMs contributed to the lower trend inflation in the region, although the decline in the former was relatively milder than in the latter group of countries. We also show that the low inflation in most Asian countries in the 2010s was also reflecting a series of common disinflationary shocks in the region, partly of transitory nature.

Second, our results show that including survey inflation expectations as forward-looking information helps in the estimation of trend inflation for all countries in our sample. Yet, the information content of survey measures seems to be particularly relevant for those countries that have announced explicit inflation targets, which often act as reference points for private sector inflation expectations.

Finally, we also show that trend inflation estimates can be crucial to better interpret survey measures of long-term inflation expectations. By construction, trend inflation estimates should be interpreted as the optimal conditional long-term inflation forecast. We use our trend inflation estimates as benchmarks for comparison to the (average) level of survey long-term inflation expectations, and the announced (mid-point if a band) level of the central bank target. For example, our country-level analysis identifies different responses of inflation expectations to the below-target inflation rates observed in some countries in the region over 2014-17. While countries like Australia and New Zealand continue to exhibit strong anchoring of inflation expectations, a more significant weakening can be observed, for example, in South Korea and Thailand. Importantly, trend inflation estimates help understand both actual inflation and inflation expectations in all those countries, and their experiences are likely to offer important lessons for other economies.

This paper contributes to the growing literature that estimates trend inflation using unobserved components models with stochastic volatility (UCSV) such as Stock and Watson (2007, 2015), Chan, Koop and Potter (2013), Clark and Doh (2014), and Mertens (2015) among others. By focusing on 12 of the largest Asian economies, our analysis expands existing international evidence on the estimation of trend inflation, in line with Garnier, Mertens, and Nelson (2015) for AEs, but also including some important EMs. In particular, our evidence on the Asian economies describes why protracted periods of persistent below-target inflation can also take place against fairly sound rates of growth, even in large EMs like Thailand, and how low inflation can affect the anchoring of inflation expectations. Our findings are complementary to the results in Kamber and Wong (2018), where global factors on inflation are shown to reflect commodity price shocks and mainly affect the inflation gap, while trend inflation remains mostly driven by domestic monetary policy. We focus on trend inflation insights for long-term inflation expectations, for central bank credibility and its implications for guiding monetary policy decisions.

The remainder of the paper is organized as follows. Section 2 discusses the motivation for trend inflation estimation and provides an overview of the different approaches that have been proposed in the literature. Section 3 describes inflation developments in Asia over our sample. Our empirical framework for the estimation of trend inflation is described in Section 4, and the main insights are discussed both from a regional (Section 5) and from a individual country perspective (Section 6). Section 7 finally concludes.

2 Core and Trend Inflation: an overview of the literature

Inflation developments are nowadays closely monitored by central banks and market participants. A standard challenge to assess inflation dynamics is that headline inflation readings tend to be somewhat volatile and some (implicit or explicit) interpretation of the observed levels is necessary to guide monetary policy decisions. What is often needed is a measure of inflation that provides an accurate gauge of the underlying inflationary pressures present in an economy at a given point in time, a "trend" value to which a forward looking monetary policy should be aimed.

A relatively large number of approaches to gauge the underlying trend embodied in the observed inflation data releases have been proposed in the literature. In principle, the observed headline inflation rate π_t can always be decomposed as $\pi_t = \pi_t^* + c_t$, where π^* denotes the persistent inflationary pressures, that is the trend inflation rate, and c_t denotes the temporary deviations of inflation from that trend usually associated to transitory or cyclical influences. While there is wide consensus on the usefulness of the underlying inflation concept, there is less agreement on the optimal approach to gauge trend inflation.

Broadly speaking, existing approaches to decompose headline inflation into persistent and transitory components can be classified in two main categories. The first approach exploits information about the cross-sectional composition of headline inflation to restrict the influence of the components associated to non-persistent fluctuations. The most popular approach in this line of reasoning is to construct measures of "core" inflation, which usually excludes food and energy prices from the price index. Core inflation measures became popular in the 1970s when large price movements in food and oil complicated the task of interpreting movements in the observed headline inflation (see Gordon, 1975, Eckstein, 1981, for early contributions and Wynne, 2008, for an overview of the use of core inflation measures over time). Other versions of the component exclusion approach include trimmed mean and median inflation measures (e.g. Bryan and Cecchetti, 1994), which restrict the volatility of inflation by excluding the components displaying the largest changes—in any direction—in a given month.

While core inflation measures are easy to construct and to understand, they also have some important shortcomings from a conceptual point of view. First, they only consider the cross-sectional composition of headline inflation, assuming that the source of transitory influences (e.g. energy and food prices) is constant over time, and ignoring useful information in the behaviour of inflation over time that may be crucial to gauge the persistent component of inflation. For example, while during the large oil price shocks of the 1970s it may have been reasonable to exclude temporary oil price increases from headline inflation systematically, nowadays other components may also have somewhat more persistent effects. Similarly, excluding components that display large price changes through trimmed mean and median measures may also remove useful information of changes in trend inflation. Rich and Steindel (2007) provides a comparison of several core inflation measures in the U.S. and concludes that the performance of different core measure varies with the sample due to the fact that there is considerable variability in the nature and sources of transitory price movements.

For an international perspective like the one taken in this paper, standard core inflation measures also have an additional shortcoming. Excluding mechanically energy and food components from the official CPI index may imply removing a very different percentage of the consumption basket across countries, for the CPI basket composition is country-specific. For example, among the Asian countries we consider in this paper, removing food and transport prices would imply excluding about 26 percent of the consumer basket used in the CPI calculation in Australia, while excluding similar basket components in Thailand would be above 27 percent, more than

29 percent in Malaysia, almost 50 percent in India, but only about 21 percent in South Korea.

To overcome those limitations of simple core inflation measures, a large number of model-based techniques have been proposed in the literature. This second category of approaches includes both time-series techniques—often in the context of univariate frameworks—like the integrated moving average (IMA) model of Nelson and Schwert (1977), the four-quarter moving average model of Atkeson and Ohanian (2001), the exponential smoothing model of Cogley (2002), and more standard multivariate macromodels like Gordon (1982) "triangle"-type models.

More recently, and to a large extent motivated by some puzzles on inflation developments and long-term inflation expectations after the GFC, there has been a renewed interest on the estimation of trend inflation in the context of unobserved component models popularized by Stock and Watson (2007). Among others, Chan, Koop and Potter (2013), Bednar and Clark (2014), Amstad, Potter and Rich (2014), Stock and Watson (2015), and Mertens (2015) have extended the standard framework on several dimensions to provide alternative estimates of trend inflation, mainly for the U.S. economy, although some evidence is also available for several advance economies (e.g. Garnier, Mertens, and Nelson, 2015), Japan (e.g. Takahashi, 2016), and the euro area (e.g. Jarozinski and Lenza 2018, Garcia and Poon, 2018).

Our empirical approach follows Chan, Clark and Koop (2018), where, building on earlier work (e.g. Kozicki and Tinsley, 2012) to acknowledge the important role of long-term inflation expectations in inflation dynamics, survey measures are incorporated into the estimation of trend inflation. A key feature of such an empirical framework, in contrast to earlier literature, is that trend and survey measures are not equated by assumption. Instead, our specification allows for the potential level of trend inflation and the reported level of survey inflation expectations to differ, with that difference varying over time. Such flexibility allows for assessing the information content of survey expectations for the conduct of monetary policy in each individual country, and identify potential episodes of de-anchoring of inflation expectations when they take place.

This paper will focus on trend inflation insights for the conduct of monetary policy in terms of the analysis of inflation dynamics for enhanced communication and the assessment of long-term inflation expectations to gauge central bank credibility. To that end, we have argued that trend inflation estimates are in principle better than standard core inflation measures based on exclusion items. For practical monetary policy implementation a large part of the debate on alternative measures of underlying inflation has been focused around their relative forecast performance. Even at an individual country level, assessing the forecast capabilities of alternative underlying inflation measures requires an empirical framework whose specification necessarily implies some relatively arbitrary choices (for a detailed discussion see e.g. Rich and Steindel, 2007). Given the heterogeneity of inflation experiences and the different degree of development of monetary policy regimes among the countries in our sample, a comprehensive analysis of forecast performance is beyond the scope of this paper.

Bearing those considerations in mind, Table 1 presents some within-sample evidence based on the root mean square forecast error (RMSE) of the standard official core inflation measure reported by each country (broadly speaking excluding the volatile energy and food inflation components) and our trend inflation estimates for headline inflation rates. More specifically,

$$RMSE = \sqrt{\frac{1}{N}\left(\sum_{i=1}^{N} e_i^2\right)}$$

where e_i is the forecast error, defined as the observed inflation rates less the underlying inflation measure (core or trend inflation), computed at the two-year horizon to account for a standard period over which the impact of monetary policy decisions on inflation could be assessed.[1]

Table 1 results suggest that trend inflation measures have a good forecast performance for inflation. For all countries but Indonesia, the RMSEs of trend inflation estimates are lower than those for the official core inflation measures.[2] It has to be borne in mind, however, that the performance of underlying inflation measures is influenced by the specific sample under consideration. Indeed, one of the main reasons why there is still lack of consensus on the appropriate measure of underlying inflation is that their forecast performance is often found to vary over time. Evidence for Asia also supports that assessment. For example, results for a more recent post-GFC subsample 2010-2018 show that trend inflation estimates have on average outperformed standard core measures in most countries over recent years, now with the exception of India and New Zealand, but, in contrast to the full sample evidence, including Indonesia.

We interpret that relative forecast performance as providing strong support for the information content of trend inflation estimates. A comprehensive assessment of the forecast properties information content of trend inflation estimates, and any underlying inflation measures, is however likely to require a multivariate setting in which proper additional variables are selected on a country basis. Yet, an optimal inflation forecast model to guide monetary policy decisions over

[1] Results at a one-year horizon are qualitatively similar in most countries in our sample.

[2] In our full sample calculations, we restrict our comparison to the periods in which official core measures have been published in each country (see e.g. Haver and National Statiscial Institutes for the specific periods).

time is also likely to incorporate some judgement on the nature of transitory shocks afflicting the economy at a given point in time, and also the degree of anchoring of inflation expectations. A key goal of this paper is to show that trend inflation estimates can provide crucial information in those two dimensions.

3 An Overview of Inflation developments in Asia 1996-2018

Before discussing our modeling and estimation of trend inflation, Table 2 provides some basic descriptive statistics of annual inflation rates in Asia. The evidence is based on monthly year-on-year inflation rates in 12 Asian economies between January 1995 and June 2018.[3]

There are several key insights from Table 2. First and foremost, there is significant heterogeneity in the inflation experiences among Asian economies. Over the last two decades inflationary pressures appear to be very well contained among AEs, probably reflecting that those economies introduced inflation targeting regimes in many cases in the early part or even before the start of our sample (e.g. New Zealand in 1990, Australia in 1993, Korea in 1998). EMs in Asia have, in contrast, experienced higher average and more volatile inflation rates than most of the AEs over the sample as a whole, which in turn may also be related to their more recent adoption of formal inflation targeting (e.g. Philippines in 2002, Thailand in 2002, Indonesia in 2005, and India as recently as 2016).

Second, all countries in our sample have experienced both some high inflation episodes with consumer prices rising by more than 5 percent, and also deflationary episodes. High inflation episodes tend to be concentrated in the earlier years of our sample in most cases, but, despite its well known struggle with low and negative inflation rates over the last two decades, even Japan experienced almost 4 percent inflation for a brief period in 2014. Instead, negative or very low inflation rates used to be normally associated to cyclical downturns, with the more recent episode since 2014 being an exception.

Finally, while for many countries those severe deflationary episodes took place in the aftermath of the Asian Financial Crisis (AFC), most of them have weathered relatively well the disinflationary pressures that spread worldwide following the GFC. Somewhat surprisingly, however, inflation in some Asian countries (e.g. Thailand, Korea, New Zealand) appeared to be more vulnerable to the protracted decline in commodity prices over 2014-16.

[3] The start of the sample is motivated by the availability of survey long-term measures of inflation expectations in most countries in the region.

Evidence from different expenditure categories within the CPI basket suggests that the decline in inflation in Asia since 2011 has been fairly broad-based (see IMF, 2018, for a detailed discussion): declines across food, other goods, and services price inflation have been quantitatively similar, and across both tradable and non-tradable goods inflation as well. Importantly, it was also shared by AEs and EMs in the region.

Bearing in mind the individual country experiences, one of our goals in this paper is to provide an analysis of inflation dynamics that helps ascertain the nature of the forces behind the fluctuations of inflation in the individual countries, but also to shed light on which part of those fluctuations are shared across Asian countries and why they have manifested in stronger effects across countries.

4 Econometric Modelling of Trend Inflation

We estimate trend inflation in the context of an unobserved component framework along the lines of Stock and Watson (2007) and particularly the recent contribution by Chan, Clark and Koop (2018). Within such a framework, inflation is generally assumed to have two (unobserved) components, $\pi_t = \pi_t^* + c_t$, where π^* denotes the trend inflation rate and c_t denotes the temporary deviations of inflation from that trend, that is the (cyclical) inflation gap $\pi_t - \pi_t^*$. Those components can be estimated assuming a generalization of the Beveridge-Nelson decomposition, where the permanent component or "trend" in inflation π^* reflects the most likely inflation rate to be observed once the transitory influences on inflation die away, and can therefore be interpreted as the optimal conditional long-term inflation forecast. Formally, $\lim_{j \to \infty} E[\pi_{t+j} \mid I_t] = \pi_t^*$, while $\lim_{j \to \infty} E[c_{t+j} \mid I_t] = 0$, where I_t denotes the available information at time t. Observed inflation is therefore decomposed into its trend, which follows a random walk process, and the inflation gap that follows a stationary process with zero mean.

Following Chan et al. (2018), we also incorporate information about long-term inflation expectations into the estimation. The purpose is twofold. First, long-term inflation expectations are widely acknowledged to exert an important influence on inflation dynamics. Their inclusion incorporates forward-looking information into trend inflation estimation in a flexible but explicit way (to be detailed below). In addition, trend inflation estimates may shed light on another important piece of information for monetary policy, namely the extent to which available survey measures of long-term inflation expectations are consistent with the observed inflation developments, or, as argued for some major economies like the U.S. (e.g. Chan et al., 2018) and the euro area (Garcia and Poon, 2018), may have become somewhat more disconnected from actual inflation developments after the GFC.

To allow for potential changes over time in the inflation process over our sample, our empirical framework comprises time-varying parameters. In addition, our empirical framework also allows for some key additional features that have been found important in this kind of models, like stochastic volatility, modelling inflation in terms of an inflation gap $\pi_t - \pi_t^*$, that, although stationary, it is allowed to exhibit some persistence. We will refer to our benchmark specification using survey long-term inflation expectations as UCSV-SUR. As alternative specification we will also report results from a restricted model specification only using backward-looking information (realized inflation), the UCSV-BL model.

Formally, our benchmark empirical framework UCSV-SUR comprises the following set of equations:

$$\pi_t - \pi_t^* = b_t(\pi_{t-1} - \pi_{t-1}^*) + v_t, \quad v_t \sim N(0, e^{h_{v,t}}), \tag{1}$$

$$\pi_t^* = \pi_{t-1}^* + n_t, \quad n_t \sim N(0, e^{h_{n,t}}), \tag{2}$$

$$b_t = b_{t-1} + \epsilon_{b,t}, \quad \epsilon_{b,t} \sim TN(0, \sigma_b^2), \tag{3}$$

$$SUR_t = d_{0,t} + d_{1,t}\pi_t^* + \epsilon_{z,t} + \psi\epsilon_{z,t-1}, \quad \epsilon_{z,t} \sim N(0, \sigma_w^2), \tag{4}$$

$$d_{i,t} - \mu_{i,t} = \rho_{d_i}(d_{i,t-1} - \mu_{d_i}) + \epsilon_{d_i,t}, \quad \epsilon_{d_i,t} \sim N(0, \sigma_{d_i}^2), \quad i = 0, 1, \tag{5}$$

$$h_{i,t} = h_{i,t-1} + \eta_{h_i} \ , \quad \eta_{h_i} \sim N(0, \sigma_{h_i}^2), \quad i = v, n. \tag{6}$$

Equation (1) is a commonly used standard measurement equation that relates current inflation π_t and trend inflation π_t^* to past inflation and past trend inflation respectively, expressed in inflation gap form, $\pi_t - \pi_t^*$, as has become standard in the related literature. The b_t is a time-varying parameter that measures the evolution of the degree of persistence in the inflation gap. Note that a truncated normal is assumed on the variance of the b_t to ensure that $0 < b_t < 1$ is satisfied, so that the inflation gap in (1) is stationary at each point of time and the conditional expectation of this process converges to zero as the forecast horizon increases. Equation (2) is the transition or state equation for trend inflation π_t^*.

In the spirit of the UCSV model and a transparent international comparison, our framework does not incorporate additional variables, mainly economic activity, influencing inflation dynamics. While there is some evidence pointing at a very limited contribution of real variables to inflation forecast (e.g. Stock and Watson, 2009, Faust and Wright, 2013), connections between inflation persistence and economic activity (as incorporated in Morley, Piger, and Rasche, 2015, for example), may be particularly important in some countries. Our purpose here is to provide novel evidence on trend inflation estimates for many Asian economies using an already fairly rich but tractable framework, and leave further expansions of the model for further research.

Equation (4) is fundamental for the main goal of this paper, and we provide some additional information on its interpretation here. In the spirit of the standard Mincer-Zarnowitz equation, long-run survey inflation expectations SUR_t are related to the long-term inflation trend π_t^* through a slope coefficient $d_{1,t}$ an intercept $d_{0,t}$. The slope parameter captures the impact of the long-term inflation trend on the (average of) panelists' reported long-term inflation expectations. To the extent that π_t^* is a natural benchmark long-term forecast for inflation conditional on the observed history of inflation, a strong link between the observed survey expectations and trend inflation estimates should be expected. The intercept $d_{0,t}$ in turn reflects a potential level "bias" between expected inflation as measured by surveys and trend inflation estimates. Equation (5) is the transition or state equation for the time-varying parameters $d_{i,t}$ governing the link between trend inflation π_t^* and the observed survey expectations SUR_t. Importantly, since both parameters are allowed to vary over time, our analysis allows for an evaluation of how the relationship between survey expectations and trend inflation has evolved over time. We discuss that relationship, which provides fundamental information for monetary policy purposes, in Section 5 below. Finally, equation (4) also includes an MA(1) error term to capture changes in survey expectations that may not be fully captured by the persistence in trend inflation.

This model also allows for stochastic volatility within the inflation gap (1) and trend inflation (4) equations, which are modelled as random walk processes. Both stochastic volatility and time-varying parameters allow for changes in the inflation process over time to be fully taken into account in the estimation, and have been found to be important elements in this type of models. Lastly, all the errors stated above are assumed to be independent over time and among them.

When survey long-term inflation expectations are not included in the estimation, we will refer to the resulting specification as UCSV-BL, as the model only includes backward-looking information in the form of realized inflation. Formally, equation (4) and the associated dynamics for the time-varying parameters (5) would not be part of the estimation of the UCSV-BL model.

The model is estimated using Bayesian methods to implement a Markov Chain Monte Carlo (MCMC) algorithm. Precise details on the estimation method are provided in the Appendix.

5 Trend Inflation In Asia

This section provides some statistical evidence and a regional perspective based on our trend inflation analysis, before we describe in some greater detail the insights our empirical framework offers at individual country level.

Over the last two decades, Asian economies have achieved a substantial decline in the level (and volatility) of inflation rates, in line with those of comparable economies since 2010. This being said, it is important to bear in mind the significant heterogeneity on inflation experiences in the region: for example Japan has suffered a protracted period of too low inflation (including deflation), while India has been struggling with relatively high inflation for most of our sample. Importantly, however, while helpful to guide discussion, the heterogeneity in Asian inflation experiences cannot be easily reduced to advanced versus emerging economies either. For example, among EMs, Indonesia has experienced very high inflation episodes in the first half of our sample, but a gradual decline in inflation over recent years has been observed. At the same time, Thailand kept inflation low and stable since the early 2000s—indeed was often considered as a very successful inflation targeter among EMs— but, since 2013, it has experienced very low inflation including a protracted period of 16 consecutive months of negative inflation rates between 2015-16. Similarly, other AEs, like Hong Kong SAR, also had relative high inflation (above 4 percent) between 2011-14, although it has moderated more recently. This heterogeneity in inflation experiences is what makes the analysis of inflation experiences among Asian economies challenging, but at the same time very relevant from the perspective of many other countries and regions.

This section uses our inflation decomposition to characterize inflation developments in Asia from a historical perspective, but our discussion will focus on the experiences and monetary policy challenges faced by Asian countries over more recent years. Specifically, inflation started a gradual decline across Asia in early 2012, but intensified since 2014 driven by the decline in oil and commodity prices, and by end-2015 headline inflation was less than 2 percent in almost 70 percent of the countries in our sample. This is somewhat surprising, for growth rates in the region remained among the highest among comparable economies. However, low inflation persisted until well into 2017, when the recovery in regional and global economic activity gained momentum, and the pick-up in oil prices exerted some upward pressure on inflation rates over 2018. Towards the end of 2018, however, the sharp correction in oil prices and the uncertainties surrounding global economic activity seem to have taken a toll on headline inflation rates, which moderated significantly and cast doubts on whether the rebound of inflation will be sustained and low inflation has been left behind.

5.1 Preliminary Evidence

Table 2 reports some basic statistics for headline, core and trend inflation in the region. Standard core inflation measures are somewhat less volatile than headline. However, for most countries in our sample they exhibit significant volatility, which suggests that they may still provide a rather noise signal for monetary policy making. Estimates of trend inflation are, in contrast, considerably smoother than actual inflation. This is also reflected in the significant role of transitory (or cyclical) factors in the decomposition of inflation provided in the regional evidence (Figure 1) and country-specific Figures (see Panel A in Figures 2 to 13). Indeed, trend inflation estimates are also significantly smoother than the standard core measures based on the exclusion of the energy and food components. The standard deviation of trend inflation over our sample as a whole is 2 to 5 times lower than that of core inflation for most countries. It is still just broadly similar for Malaysia, and only higher for China, where full sample figures appear to be influenced by the high levels of inflation in the early years of our sample. Given the nature of optimal conditional inflation forecast over the long-term, the lower volatility of trend inflation estimates is somewhat natural, but it also underscores the information content of its changes as important signal for forward-looking monetary policy.

Against this background, we use our model to provide quantitative evidence on the extent to which the observed low inflation reflected just transitory influences, or was instead driven by more permanent forces. We first focus on the regional perspective, looking at aggregate measures for our 12 Asian economies (median and interquartile ranges), and also investigate the robustness of the main insights for the two subgroups of Advance and Emerging economies in our sample.

5.2 A Regional Perspective on inflation developments

From a regional point of view, a decomposition of Asian inflation into trend and transitory components shows that the bulk of the decline in inflation in Asia over the last two decades reflects lower trend inflation (Figure 1). Specifically, three qualitatively distinct periods can be identified in the decline in trend inflation in the region. There was a gradual, yet very significant, decline in trend inflation between 1995 and 2002, when it halved from almost 4 percent to almost

2 percent. Interestingly both AEs and EMs contributed to the lower trend inflation in the region, although the decline in the former (3 percent to 2 percent) was relatively milder than in the latter (from around 6 percent to 3 percent).

Between 2003 and 2013 the region experienced a second phase characterized by the stability in trend inflation levels. Such a long period of stability is particularly noticeable. First, it suggests a substantial improvement in the control of inflation by central banks in the region since the early 2000s, most likely reflecting the improvement in monetary policy frameworks and the better anchoring of inflation expectations. Indeed, the size of the transitory shocks to inflation during the period does not suggest a moderation with respect to the previous period, at least over the region as a whole. Second, this period of stability of inflation includes the GFC. Although Asia may have been relatively less affected by financial market turbulences than other regions, it was similarly impacted by the strong fluctuations in oil and commodity prices in the aftermath of the GFC, as the sharp decline into negative territory in the transitory inflation component shows. Against this background, trend inflation remained broadly unchanged in most countries providing stability to inflation dynamics and allowing for the sharp rebound in inflation rates to more normal levels shortly after the Lehman collapse.

The most recent period since 2014 showed a somewhat more puzzling decline in inflation rates across Asia. Recurrent fluctuations in oil and commodity prices and also food prices, in particular the declines in 2014-15, triggered a cluster of negative transitory shocks in recent years. This evidence is consistent with the findings in Kamber and Wong (2018), where global factors driving inflation in the region are shown to reflect mostly commodity price shocks and mainly affect the inflation gap. While the magnitude of those transitory shocks does not seem to be particularly large by historical standards, and clearly smaller than during 2008-09, the protracted period of negative inflation pressures, albeit predominantly transitory in nature, lowered headline inflation in the region, in some cases into some long spells of negative inflation rates (Japan, Thailand). Somewhat more surprising was the subtle downward slide in trend inflation. Such decline was more evident in EMs, but was also shared among AEs. Moreover, given that it has taken place at already relatively low levels of headline inflation, the lower trend inflation helps understand the protracted period of below target inflation among both country blocks, and the missing pick up in inflation rates after the rebound in economic activity, particularly since 2017. We analyze the implications at country level and the challenges it may pose for monetary policy next.

6 Trend Inflation and Expectations: Country Level Analysis

This section reports in greater detail the country-by-country evidence from our empirical framework. Before discussing the individual country experiences, we first describe the how trend inflation estimates are used to analyze inflation dynamics and long-term inflation expectations.

6.1 Insights from Trend Inflation Estimation

To discuss how trend inflation estimation can inform inflation analysis and the assessment of inflation expectations in each country, the country panel figures (Figures 2-13) report several pieces of evidence. First, using our benchmark model specification— the model including forward-looking information from long-term survey inflation expectations, UCSV-SUR— we report a decomposition of the observed inflation rates into its trend and transitory components. Most AEs and some EMs, including Asia, have been afflicted by below-target inflation over most of the period 2010-18. The declines in inflation rates triggered by the GFC in 2008-09 were quite sharp, but the rebound was also strong, and low inflation was relatively short-lived in most countries. In contrast, since 2010 inflation has been relatively low, in some cases surprisingly so, and difficult to sustain over time, despite an overall accommodative monetary policy stance in many countries and favorable global financial conditions (e.g. IMF, 2016). In particular, the sharp correction in oil prices in 2014-15 triggered a protracted period of low inflation in many countries, including many Asian ones. We will use the decomposition of inflation dynamics based on our model to discuss the extent to which the low inflation rates experienced in many Asian countries since 2014 were mainly transitory, or may point to a lasting period of low inflationary pressures.

Next, we investigate how to interpret the information content of survey (long-term) inflation expectations to guide monetary policy. We will argue that trend inflation estimates can offer very valuable insights. First, Figures 2-13 (Panel B) will report the trend inflation estimates for two model specifications, our benchmark specification UCSV-SUR, and a restricted specification, the UCSV-BL, in which trend inflation estimation is solely based on realized inflation, that is, only incorporating backward-looking information. Overall, our findings provide strong support for survey data information for the estimation of trend inflation.

Second, since by construction trend inflation estimates should be interpreted as the optimal conditional long-term inflation forecast, we use our trend inflation estimates as benchmarks for comparison to the (average) level of survey long-term inflation expectations, and the announced (mid-point if a band) level of the central bank target. Such a comparison allows for drawing conclusions on the evolution of central bank credibility, the strength of the expectation channel on inflation dynamics, and the information content of survey long-term inflation expectations (see Figures 2-13, Panel B).

Overall, trend inflation estimates and survey-based measures share the decline over the 1990s in many countries where monetary policy frameworks were undertaking significant improvements. While long-term survey expectations have displayed some volatility, particularly in the earlier part of our sample, evidence suggests that they have tracked major historical patterns in inflation quite well. Moreover, over recent years, in most countries they are broadly aligned with the announced inflation target: ranging from a practically perfect alignment in some countries (e.g. Australia, New Zealand, China, Hong Kong) to somewhat looser in some others (e.g. Indonesia, Thailand, Korea). Japan, where there is a substantial and statistically significant discrepancy between the official inflation target of the Bank of Japan and much lower survey forecasts, is an extreme case.

The comparison between the levels of trend inflation estimates and survey long-term inflation expectations is particularly relevant since the GFC. Despite extended periods of below-target inflation in several AEs, survey long-term inflation expectations remained relatively unchanged with respect to the pre-GFC levels. That evidence has raised concerns that survey inflation expectations may have become too disconnected from actual inflation developments, which has important implications for inflation forecasting and to gauge the credibility of monetary policy. Indeed, recent research has shown evidence of a potential disconnection between survey long-term inflation expectations and inflation developments in the U.S. (Chan et al., 2018), the euro area (Garcia and Poon, 2018) and even earlier for Japan (Fuhrer et al., 2010). Our analysis of survey measures of long-term inflation expectations among the largest Asian economies can shed new light on that debate. Indeed, our trend inflation estimates offer several important insights when compared to the level of survey long-term inflation expectations and the announced inflation targets. Overall, the statistical uncertainty surrounding trend estimates suggests that trend inflation has been significantly below the reported survey forecasts in a statistically significant sense in some Asian economies as well. But the relevance of the discrepancy between long-term survey and trend inflation is particularly important for some countries.

Finally, we report the volatility to the shocks to both the trend and the inflation gap or transitory factors (Figures 2-13, Panels C and D). They provide important evidence of the drivers of the key inflation components and how they have varied over time, which in some cases may be very helpful to infer the impact of the evolution of the monetary policy regime on inflation dynamics in the country. We focus on the model-based evidence that is more relevant for monetary policy and for a comparison across countries. We will not report systematically on other model estimation results, and, for example, restrict explicit references to changes over time in the persistence of transitory inflation influences—measured by the parameter b_t in our model— or the two metrics governing the time-varying differences between survey measures and trend inflation estimates— the slope coefficient $d_{1,t}$ and the intercept $d_{0,t}$ in equation (4)— to those cases in which they are important to fully understand the insights for a specific country (for a more detailed discusion and additional country experiences see Garcia amd Poon, 2019).

6.2 An Overview of Country Experiences

In countries like China, Taiwan and Hong Kong, survey inflation expectations appear to be very much aligned with trend inflation estimates over recent years, and those countries have experienced fairly stable inflation rates lately (see Figures 3, 4 and 12), despite facing transitory inflation pressures of similar magnitude to other countries in the region. Overall, the inflation experiences in these three countries seem to reflect the gradual improvement in their monetary policy frameworks towards the fairly sound stability in inflation rates and inflation expectations they have enjoyed in recent years.

Australia and New Zealand offer a different experience: while survey inflation expectations are strongly aligned with the (mid-point) inflation target announced by the central bank— reflecting the strong credibility of the central banks— trend inflation has been below that level in recent years, which helps explain why inflation outturns have been below-target, and most likely could remain so in a near future (see Figures 2 and 10). The strong anchoring of inflation expectations in those two countries explains the significant differences in the trend inflation estimates between the two model specifications, UCSV-SUR and UCSV-BL. While the backward looking model also points to weak inflationary pressures in both countries, incorporating the information content of survey measures of long-term inflation expectations provides much more stable trend inflation estimates.

Interestingly, however, the fact that trend inflation estimates have been persistently below long-term survey expectations points to the presence of a sizable (and statistically significant) "bias" in survey measures. Formally, in the context of our empirical framework, the estimates of the intercept parameter $d_{0,t}$ in equation (4) are significantly greater than zero in statistical sense, while the slope parameters $d_{1,t}$ remain close to their theoretically-consistent value of 1. Given the strong credibility of the Reserve Banks in those two countries it is likely that such a bias just reflects the power of a (mid-point) target announcement on inflation expectations. In any case, our trend inflation estimates suggest that the central banks should monitor carefully the level of survey inflation expectations, and ensure that the below-target inflation does not trigger a downward revision in their level that could make more difficult a sustained return of inflation back to target.

Differences between trend inflation and survey long-term expectations may point to more challenging situations for other countries. For example, Japan has provided evidence that actual inflation can run consistently below survey measures of long-term inflation expectations for a considerable period of time (see Figure 7, Panel A, and for example Fuhrer, Olivei, and Tootell, 2012, for a discussion). Moreover, trend inflation estimates for Japan, that have been persistently below the inflation target since the early 2000s, help explain the weak inflation rates observed in the country, and also the fast return to low inflation after the temporary spike experienced in 2014.

Indonesia, in contrast, seems to have struggled to align private sector expectations with the gradual revision in the (mid-point) inflation target since 2015 (see Figure 6). Importantly, however, the fact that trend inflation remained more aligned to the inflation target, and significantly below the survey measures, pointed to actual inflation realizations turning out in line with the target, and also help understand the downward revision of long-term survey expectations over 2018.

South Korea and Thailand have also experienced protracted periods of below-target inflation since the GFC, and particularly following the sharp decline in oil prices in 2014-15. In their cases, trend inflation estimates suggest a more protracted disconnection both between the inflation target and actual inflation developments, and between the levels of trend inflation and survey long-term inflation expectations, which deserve greater attention. Indeed, while some of the downward inflationary pressures in those countries were of transitory nature, and similar to those in other countries in the region (see Figures 2 and 13, Panel A), the declines in trend inflation in Thailand and South Korea show that the downward pressures on inflation had a more persistent nature, and therefore pose a bigger challenge for monetary policy. A contribution of this paper is to show how trend inflation estimates could be particularly useful for monetary policy making and inflation analysis in those circumstances.

South Korea has experienced a protracted decline in headline inflation since the 1990s, which has taken place along a very gradual moderation in growth rates. More recently, in particular since 2012, low inflation appeared to become more entrenched, while economic activity, despite some fluctuations, seemed to be relatively stable, with annual growth fairly stable at around 3 percent on average in the 2010s. Indeed, trend inflation estimates have been on a continuous downward trend since the mid-1990s. Survey long-term expectations, also on a downward trend, have run consistently, and in a statistically significant way, above trend inflation estimates most of the time.

The comparison between survey long-term inflation expectations and trend inflation measures in the case of South Korea is particularly noticeable for several reasons. First, survey expectations have exhibited more significant fluctuations than in the cases of Australia and New Zealand discussed above. In particular, they have tracked well the protracted moderation in headline inflation (and the steady decline in trend inflation) over our sample as a whole. However, their comparison to trend inflation over time can offer important insights for both research and monetary policymaking.

In particular, the decision of the central bank to lower the inflation target in response to the protracted below-target inflation experienced between 2010 and 2015 marked a crucial episode for analysis. The inflation target was lowered to 2 percent in 2016, down by 1 percent. Headline inflation rates have however been below that new target level most of the time since then. Moreover, survey long-term inflation expectations have also been revised downwards to levels below the new inflation target. While the alignment of survey inflation expectations with the announced inflation target by the Central Bank of Korea has been relatively loose since 2010, survey expectations have also experienced significant differences to trend inflation. For example, survey expectations were more aligned to the then announced target of 3 percent in 2010-12, while significantly above a lower (and declining) trend inflation of around 2.25 over the period 2013-2016. With long-term expectations and trend inflation already below the previous target of 3 percent for several years, the downward revision in the target mainly "validated" those lower inflation expectations. With the revision of the inflation target in 2016, survey measures were temporarily more aligned again to the new target of 2 percent in 2016-17. The downward revision of the inflation target, however, did not stop the decline in trend inflation. From 2017 onwards, survey expectations have been revised further downwards, to levels broadly consistent, in statistical sense, with trend inflation estimates. This evidence provides strong support for trend inflation estimates as optimal conditional forecast for long-term inflation and useful benchmark for interpreting survey inflation expectations. Indeed, it suggests that modelling a time-varying relationship between survey long-term inflation expectations and trend inflation can help central banks better interpret and, in some circumstances, even to anticipate movements in survey expectations.

Trend inflation estimates have been below the new inflation target in a statistically significant way over 2018, pointing to a continuation of subdued inflation pressures. Trend inflation estimates from UCSV-BL exhibit higher fluctuations over time, but also point to a protracted decline in trend inflation over the sample as a whole, and particularly weak inflationary pressures from around 2013 that may have only moderated somewhat in 2018.

In the case of Thailand, the period of below-target inflation is restricted to the last part of our sample. This is quite noticeable because, despite somewhat volatile survey long-term inflation expectations over a sample as whole pointing to some imperfect credibility of the central bank's target, Thailand was a very successful inflation targeter among EMs, with headline inflation quite stable in the 3-5 percent range since the AFC. While remaining significantly below survey measures, trend inflation was broadly stable around 2.5 percent between 2003 and 2015. The announcement of an explicit target band for headline inflation (2.5 percent±1.5 percent) at the end of 2015 however coincided with significant downward pressures on inflation stemming from the sharp decline in oil prices. While part of those pressures were of transitory nature (see Figure 13, Panel A), and quantitatively similar to those in other countries in the region, the gradual decline in trend inflation, which intensified since 2016 becoming significant—both in statistical and economic sense— below the (mid-point) inflation target, has also been pointing to the presence of rather persistent disinflationary pressures. Inflation remained in negative territory for 15 consecutive months between 2014-16, and has been below the mid-point (and even outside the target band) for long periods since then. Indeed, the UCSV-BL model point to some of the strongest disinflationary pressures in the region as a whole.

Against this background, survey inflation expectations have also been revised downwards significantly over recent years. After remaining even above the mid-point inflation target (and trend inflation) until 2017, survey long-term inflation expectations were revised sharply downwards since then, towards levels around 2 percent, more in line with the trend inflation estimates.

Thailand's low inflation experience also provides strong evidence in support of the usefulness of trend inflation estimates to interpret underlying inflationary pressures, and to complement the information from survey measures of long-term inflation expectations, particularly when there may be signals of a de-anchoring of inflation expectations. Moreover, Thailand is one of the few countries in our sample over which the persistence of the inflation gap $\pi_t - \pi_t^*$ — measured by the parameter b_t in equation (1)—has experienced a slight increase towards around 0.5, a value in the upper part of the distribution of estimates among the countries in our sample, which also contributes to explain the persistence of low inflation in the country.

Evidence from some Asian countries may also offer interesting insights for other countries based on their particular inflation experiences. India, for example, had been struggling with episodes of relatively high inflation and supply shocks. With more formal inflation targeting since June 2016 to reinforce price stability—defined in terms of a target band (4.0±2 percent)—as primary objective for monetary policy, the Reserve Bank of India has enhanced its analytical framework (for a discussion see Benes et al., 2017), and managed to keep inflation at fairly low levels by historical standards since then. Despite somewhat volatile (and above target) survey inflation expectations, the trend inflation estimates based on our benchmark model have been fairly stable, and broadly consistent with the definition of price stability, attributing the high headline inflation between 2009 and 2014 mainly to a series of transitory shocks. Interestingly, there is a significant difference between trend inflation estimates between our benchmark specification and the purely backward-looking estimation. The latter, in the absence of additional information, tends to track too closely actual inflation realizations, and is particularly striking in the case of India. Looking ahead, to the extent that the level and volatility of trend inflation shocks remain fairly stable, further convergence of trend and survey expectations to the official inflation target should be expected.

Malaysia also offers an interesting example of fairly stable inflation since the 2000s without adopting a formal inflation targeting framework. Indeed, our trend inflation estimates have fluctuated within a narrow band of 2-3 percent over most of our sample since the early 2000s, despite fairly volatile survey inflation expectations, and the size of the transitory component of headline inflation is also comparable to that of similar countries. Through gradual improvements in the monetary policy framework (see for example Dany-Knedlik and Garcia, 2018, and references therein) Bank Negara Malaysia has delivered fairly stable inflation and supported economic activity in the country. Interestingly, the lack of an explicit inflation target may be however behind the significant volatility of survey measures of inflation expectations, and, in turn, help explain why in this case UCSV-SUR and UCSV-BL models offer very similar trend inflation estimation results.

The Philippines is one of the few countries in the region which has experienced fairly high inflation rates in the 2010s. While the country has experienced high inflation episodes in the past, the sharp rise in inflation following the rebound in oil prices over 2018 was somewhat unique in the region. The estimation of trend inflation for The Philippines within our framework faces some special challenges, since survey long-term inflation expectations are only available since 2009. That helps explain why estimates are relatively similar both for our benchmark specification and for the purely backward-looking model, and also surrounded by higher uncertainty than for other countries. This being said, trend inflation estimates have been more volatile than for peer countries, and have moved from well below the inflation target in 2015-16 to well above it in 2018.

Finally, our empirical framework also provides additional information on the changes over time in the volatility of the inflation process. More specifically, in addition to the time-varying persistence in the dynamics of each of the two different components of observed inflation, the trend and the inflation gap components, our empirical analysis provides separate estimates of the stochastic volatility affecting each of those components. Allowing for the magnitude of shocks to the inflation trend and the transitory component can help understand the nature of the factors driving inflation in the different countries. Moreover, in the case of trend inflation, together with its level, the magnitude of trend shocks may shed light on the degree of anchoring of inflation expectations.

There are significant differences in the presence of stochastic volatility for trend inflation among the economies in our sample (see Figures 2-13, Panels C and D). We interpret this finding as reflecting the different degree of development in the monetary policy framework of Asian economies over the last two-three decades. As expected, a well-established monetary policy regime seems to be associated with low volatility of trend estimates, at least over our sample. Overall for the countries that have introduced formal inflation targets/bands as part of their monetary policy regime, trend inflation levels and the volatility of trend shocks have tended to decrease, but often after some time, reflecting the need for an adjustment period. It is then not surprising that countries with a more recent improvement of their monetary policy frameworks do display higher volatility of trend inflation in the early years of our sample. Moreover, despite a remarkable decline in trend inflation level and volatility in most EMs (e.g. China, India, Indonesia, Malaysia), there are some sizable differences in both dimensions with respect to some peer Asian countries—particularly those with well established and strongly credible monetary policy frameworks and inflation targets (e.g. Australia, New Zealand)—which suggests that there is still room for improvement in their monetary policy frameworks and communication. From a modeling perspective, in general, trend volatility shocks tend to be higher when we use the univariate model UCSV-BL than our benchmark baseline model UCSV-SUR across most countries. This explains why this model produces highly volatile estimates of the level of trend inflation for some countries, as pointed out above, and highlights the important information content of survey long-term inflation expectations about the monetary policy regime which they bring into the trend inflation estimation.

7 Concluding remarks

This paper investigates the insights of trend inflation estimation for the analysis of inflation dynamics and long-term inflation expectations. We analyze the experiences of 12 of the largest Asian countries, six Advanced (Australia, Hong Kong, Japan, Korea, New Zealand, and Taiwan) and six Emerging economies (China, Indonesia, India, Malaysia, Philippines, and Thailand) over the period 1995-2018. Our empirical framework is an unobserved component and stochastic volatility (UCSV) model, that also incorporates survey long-term inflation expectations as a source of forward-looking information in the estimation. Following Chan, Clark and Koop (2018), trend inflation and survey expectations are modelled in a flexible way that allows them to differ over time.

We focus our analysis on the interpretation of recent developments of inflation in the region, in particular the protracted disinflation forces triggered by the sharp decline in oil prices in 2014-15, and its consequences for two key aspects for monetary policy, namely to what extent the declines in headline inflation should have been expected to be just mainly temporary, and whether the anchoring of long-term inflation expectations have been impacted by low observed inflation. To the extent that many other countries worldwide have also been afflicted by a protracted period of below-target inflation recently, our findings for Asian countries can offer important lessons for many other central banks worldwide.

Our analysis reveals that most countries in the region suffered from some adverse transitory inflation shocks since 2014, but we found significant heterogeneity on their impact across Asian economies. For some countries where inflation has been relatively elevated, the downward pressure has been relatively mild and mainly transitory (e.g. India, Philippines and to some extent Indonesia). Other countries have been little impacted (e.g. China, Taiwan, Hong Kong SAR, Malaysia). And among countries where low and below-target inflation has been more protracted over time, there are some where trend inflation remains low but constant (e.g. Australia, New Zealand), which suggests that low inflation will be mainly temporarily, and those where lower trend inflation and a downward revision in survey inflation expectations point to more entrenched low inflation (e.g. South Korea, Thailand).

Further international evidence on trend inflation estimates could help better interpret changes in long-term inflation expectations, and provide valuable lessons for the conduct of monetary policy. While our analysis reveals that state-of-art trend inflation estimation offers important insights for inflation analysis and monetary policymaking, it is also important to bear in mind that such analysis may not always be easy for the central bank to communicate to the general public. Evidence on international experiences may however help, and we hope that the analysis documented in this paper is a useful step in that direction. Additional international analysis may also help test the usefulness of current modelling approaches, and identify other avenues to explore. Those extensions are in our agenda for future research.

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Appendix: Estimation approach

Priors of the Model

We implement the same priors as Chan et al. (2018) for the Model given in equation (1) to (6). Firstly, we initialize the state equations (3), (4), (5) and (6) by

$$\pi_1^* \sim N(\pi_0^*, V_{\pi^*} e^{h_{n,1}}), \tag{7}$$

$$b_1 \sim N(b_0, V_b), \tag{8}$$

$$d_{i,1} \sim N(\mu_{d,i}, \frac{\sigma_{d,i}^2}{(1-\rho_{d,i}^2)}), \quad i = 0, 1, \tag{9}$$

$$h_{i,1} \sim N(h_{i,0}, V_{h_i}), \quad i = v, n, \tag{10}$$

where $\pi_0^* = b_0 = h_{i,0} = 0$ and $V_{\pi^*} = V_b = V_{h_i} = 100$. For all the model parameters, we implement independent priors for each of them. Thus,

$$\mu_{d,0} \sim (a_0, V_\mu), \tag{11}$$

$$\mu_{d,1} \sim (a_1, V_\mu), \tag{12}$$

$$\rho_{d,i} \sim TN_{(0,1)}(a_2, V_\rho), \quad i = 0, 1. \tag{13}$$

where $TN_{(0,1)}(\mu, \sigma)$ denotes the $N(\mu, \sigma)$ distribution truncated to the interval $(0, 1)$ and we set $a_0 = 0$, $a_1 = 1$, $a_2 = 0.95$ and $V_\mu = V_\rho = 0.1^2$. These choices of prior imply relatively informative priors centered at the values which imply trend inflation is equal to long-run forecast (apart from a mean zero error). The prior for MA(1) coefficient is

$$\psi \sim TN_{(-1,1)}(0, V_\psi), \tag{14}$$

where $V_\psi = 0.25^2$. Lastly, we assume independent inverse gamma priors for the all variance parameters where

$$\sigma^2_{d,0}, \sigma^2_w, \sigma^2_{h_v}, \sigma^2_{h_n} \sim IG(\nu_j, S_j), \quad j = \sigma^2_{d,0}, \sigma^2_w, \sigma^2_{h_v}, \sigma^2_{h_n}, \tag{15}$$

$$\sigma^2_{d,1}, \sigma^2_b, \sim IG(\nu_g, S_g), \quad g = \sigma^2_{d,1}, \sigma^2_b, \tag{16}$$

where $\nu_{\sigma^2_{d,0}} = \nu_{\sigma^2_{d,1}} = \nu_{\sigma^2_w} = \nu_{\sigma^2_{h_v}} = \nu_{\sigma^2_{h_n}} = \nu_{\sigma^2_b} = 5$, $S_{\sigma^2_{d,0}} = S_{\sigma^2_w} = S_{\sigma^2_{h_v}} = S_{\sigma^2_{h_n}} = 0.04$ and $S_{\sigma^2_{d,1}} = S_{\sigma^2_b} = 0.004$. Chan et al. (2017) notes that these prior choices are relatively non-informative and they also found that these priors are fairly robust in terms of a prior sensitive analysis.

Gibbs Sampler

To simulate the posterior distributions, we follow Chan et al. (2018) and implement a nine block Gibbs Sampler that sequentially draws from each conditional posterior distribution. First, let's denote $\theta = (\psi, \mu_{d,0}, \mu_{d,1}, \rho_{d,0}, \rho_{d,1}, \sigma^2_{d,0}, \sigma^2_{d,1}, \sigma^2_b, \sigma^2_z, \sigma^2_{h_v}, \sigma^2_{h_n})'$, $\pi = (\pi_1, \ldots, \pi_T)'$, $\boldsymbol{b} = (b_1, \ldots, b_T)'$, $\boldsymbol{d} = (d_{0,1}, d_{1,1}, \ldots, d_{0,T}, d_{1,T})'$ and $\boldsymbol{h}_i = (h_{i,1}, \ldots, h_{i,T})'$. The outline of the steps are:

1. Draw $p(\pi^*|Data, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$,
2. Draw $p(\boldsymbol{b}|Data, \pi^*, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$,
3. Draw $p(\boldsymbol{d}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$,
4. Draw $p(\boldsymbol{h}_v, \boldsymbol{h}_n|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \theta)$,
5. Draw $p(\mu_{d,0}, \mu_{d,1}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\mu_{d,0},\mu_{d,1}\}})$,
6. Draw $p(\sigma^2_{d,0}, \sigma^2_{d,1}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma^2_{d,0},\sigma^2_{d,1}\}})$,
7. Draw $p(\rho_{d,0}, \rho_{d,1}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\rho_{d,0},\rho_{d,1}\}})$,
8. Draw $p(\psi|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\psi\}})$,
9. Draw $p(\sigma^2_b, \sigma^2_w, \sigma^2_{h_v}, \sigma^2_{h_n}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma^2_b,\sigma^2_w,\sigma^2_{h_v},\sigma^2_{h_n}\}})$,

Draw $p(\pi^*|Data, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$

Firstly, we can rewrite the measurement equation of (1) into

$$\mathbf{H}_b\pi = \mathbf{H}_b\pi^* + \tilde{\alpha}_{\pi^*} + v, \quad v \sim N(0, \Lambda_v) \ , \tag{17}$$

where $\tilde{\alpha}_{\pi^*} = (b_1(\pi_0 - \pi_0^*), 0, \ldots, 0)'$, $\varLambda_v = diag(e^{h_{v,1}}, \ldots, e^{h_{v,T}})'$, $v = (v_1, \ldots, v_T)'$ and

$$\mathbf{H}_b = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ -b_2 & 1 & 0 & \cdots & 0 \\ 0 & -b_3 & 1 & \ddots & 0 \\ \vdots & & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & -b_T & 1 \end{bmatrix}. \tag{18}$$

Since $|\mathbf{H}_b| = 1$ for any b, $\mathbf{H}_b$ is invertible. Therefore, we have

$$(\pi|\pi^*, \boldsymbol{b}, \boldsymbol{h}_v) \sim N(\pi^* + \alpha_{\pi^*}, (\mathbf{H}_b' \varLambda_v^{-1} \mathbf{H}_b)^{-1}), \tag{19}$$

where $\alpha_{\pi^*} = \mathbf{H}_b^{-1} \tilde{\alpha}_{\pi^*}$. Next, we can also rewrite equation (2) into

$$\boldsymbol{z} = d_0 + \mathbf{X}_{\pi^*} \pi^* + \mathbf{H}_\psi \epsilon_z, \quad \epsilon_z \sim N(0, \sigma_w^2 \mathbf{I}_T), \tag{20}$$

where $d_0 = (d_{0,1}, \ldots, d_{0,T})'$, $\mathbf{X}_{\pi^*} = diag(d_{1,1}, \ldots, d_{1,T})$, $\epsilon_z = (\epsilon_{z,1}, \ldots, \epsilon_{z,T})'$, $\boldsymbol{z} = (z_1, \ldots, z_T)'$ and

$$\mathbf{H}_\psi = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ \psi & 1 & 0 & \cdots & 0 \\ 0 & \psi & 1 & \ddots & 0 \\ \vdots & & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \psi & 1 \end{bmatrix}. \tag{21}$$

Therefore, we have

$$(z|d_0, \pi^*, \psi, \sigma_w^2) \sim N(d_0 + \mathbf{X}_{\pi^*} \pi^*, \sigma_w^2 \mathbf{H}_\psi \mathbf{H}_\psi'). \tag{22}$$

Lastly, we can rewrite the state equation of (3)

$$\mathbf{H} \pi^* = \delta_{\pi^*} + \boldsymbol{n}_t, \quad \boldsymbol{n}_t \sim N(0, \varLambda_n), \tag{23}$$

where $\delta_{\pi^*} = (\pi_0^*, 0, \ldots, 0)'$, $\varLambda_n = diag(e^{h_{n,1}} V_{\pi^*}, e^{h_{n,2}}, \ldots, e^{h_{n,T}})'$ and

$$
\mathbf{H} = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ -1 & 1 & 0 & \cdots & 0 \\ 0 & -1 & 1 & \ddots & 0 \\ \vdots & & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & -1 & 1 \end{bmatrix}. \tag{24}
$$

Therefore we have

$$
(\pi^*|\boldsymbol{h}_n) \sim N(\delta_{\pi^*}, (\mathbf{H}'\Lambda_n^{-1}\mathbf{H})^{-1}). \tag{25}
$$

To find the conditional posterior of $p(\pi^*|Data, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$, we combine (19), (22) and (25) to obtain

$$
\log p(\pi^*|Data, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta) \propto -\frac{1}{2}(\pi - \pi^* - \alpha_{\pi^*})'(\mathbf{H}_b'\Lambda_v^{-1}\mathbf{H}_b)\frac{1}{2}(\pi - \pi^* - \alpha_{\pi^*}),
$$

$$
-\frac{1}{2\sigma_w^2}(z - d_0 - \mathbf{X}_{\pi^*}\pi^*)'(\mathbf{H}_\psi\mathbf{H}_\psi')^{-1}(z - d_0 - \mathbf{X}_{\pi^*}\pi^*) - \frac{1}{2}(\pi^* - \delta_{\pi^*})'(\mathbf{H}'\Lambda_n^{-1}\mathbf{H})(\pi^* - \delta_{\pi^*}), \tag{26}
$$

$$
\propto -\frac{1}{2}(\pi - \hat{\pi}^*)'\mathbf{K}_{\pi^*}(\pi - \hat{\pi}^*), \tag{27}
$$

where the conditional posterior is

$$
(\pi^*|Data, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta) \sim (\hat{\pi}^*, \mathbf{K}_{\pi^*}^{-1}), \tag{28}
$$

where

$$
\mathbf{K}_{\pi^*} = (\mathbf{H}_b'\Lambda_v^{-1}\mathbf{H}_b + \frac{1}{\sigma_w^2}\hat{\mathbf{X}}_{\pi^*}'\hat{\mathbf{X}}_{\pi^*} + \mathbf{H}'\Lambda_n^{-1}\mathbf{H})^{-1}, \tag{29}
$$

$$
\hat{\pi}^* = \mathbf{K}_{\pi^*}^{-1}(\mathbf{H}_b'\Lambda_v^{-1}\mathbf{H}_b(\pi - \alpha_{\pi^*}) + \frac{1}{\sigma_w^2}\hat{\mathbf{X}}_{\pi^*}'\tilde{\boldsymbol{z}} + \mathbf{H}'\Lambda_n^{-1}\mathbf{H}\boldsymbol{\delta}_{\boldsymbol{\pi}^*}), \tag{30}
$$

where $\tilde{\boldsymbol{z}} = \mathbf{H}_\psi^{-1}(z - d_0)$ and $\hat{\mathbf{X}}_{\pi^*} = \mathbf{H}_\psi^{-1}\mathbf{X}_{\pi^*}$.Notice that the precision matrix $\mathbf{K}_{\pi^*}^{-1}$ is a band matrix, which means we can apply the precision sampler technique of Chan and Jeliazkov (2009) to draw $\hat{\pi}^*$. As discussed in Chan et al. (2018) most of the elements of $\hat{\mathbf{X}}_{\pi^*}$that are away from the diagonal band are close to zero. Therefore, they construct a band approximation by replacing all elements below the absolute value of 10^{-6} with zero.

Draw $p(\boldsymbol{b}|Data, \pi^*, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$

To derive this conditional posterior, the inequality $0 < b_t < 1$ must be satisfied. As a result of this inequality, this conditional posterior is non-normal, which means a Metropolis-Hasting step has to be undertaken to simulate the posterior draws. First, we can rewrite the measurement equation of (1) as:

$$\tilde{\pi} = \mathbf{X}_b \boldsymbol{b} + v, \quad v \sim N(0, \Lambda_v), \tag{31}$$

where$\tilde{\pi} = (\pi_1 - \pi_1^*, \ldots, \pi_T - \pi_T^*)'$ and $\mathbf{X}_b = diag(\pi_0 - \pi_0^*, \ldots, \pi_{T-1} - \pi_{T-1}^*)'$. Next, we can rewrite the state equation of b_t (4) into

$$\mathbf{H}\boldsymbol{b} = \tilde{\delta}_b + \epsilon_b, \quad \epsilon_b \sim N(0, \sigma_b^2 \mathbf{I}_T), \tag{32}$$

where $\tilde{\delta}_b = (b_0, 0, \ldots, 0)'$and the elements of $\epsilon_b = (\epsilon_{b,1}, \ldots, \epsilon_{b,T})'$ are independent truncated normal variables. Note that $\Pr(0 < b_1 < 1) = \Phi(\frac{1-b_0}{\sqrt{V_b}}) - \Phi(\frac{b_0}{\sqrt{V_b}})$ and

$$\Pr(0 < b_t < 1) = \Phi(\frac{1 - b_{t-1}}{\sigma_b}) - \Phi(\frac{-b_{t-1}}{\sigma_b}), \tag{33}$$

where $\Phi(.)$ is the cumulative distribution function of the standard normal distribution. Thus, the prior density for b is

$$\log p(\boldsymbol{b}|\sigma_b^2) \propto -\frac{1}{2}(\boldsymbol{b} - \delta_b)'\mathbf{H}'\Sigma_b^{-1}\mathbf{H}(\boldsymbol{b} - \delta_b) + g(\boldsymbol{b}, \sigma_b^2), \tag{34}$$

where $\Sigma_b = diag(V_b, \sigma_b^2, \ldots, \sigma_b^2)$, $\delta_b = \mathbf{H}^{-1}\tilde{\delta}_b$ and

$$g(\boldsymbol{b}, \sigma_b^2) = -\sum_{t=2}^{T} \log(\Phi(\frac{1 - b_{t-1}}{\sigma_b}) - \Phi(\frac{-b_{t-1}}{\sigma_b})). \tag{35}$$

To get the conditional posterior, we combine (32) and (35) to obtain

$$\log p(\boldsymbol{b}|Data, \pi^*, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta) \propto -\frac{1}{2}(\boldsymbol{b} - \hat{\boldsymbol{b}})'\mathbf{K}_b^{-1}(\boldsymbol{b} - \hat{\boldsymbol{b}}) + g(\boldsymbol{b}, \sigma_b^2), \tag{36}$$

Thus,

$$(\boldsymbol{b}|Data, \pi^*, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta) \sim N(\hat{\boldsymbol{b}}, \mathbf{K}_b^{-1}) \tag{37}$$

where

$$\mathbf{K}_b = (\mathbf{H}^{'}\Sigma_b^{-1}\mathbf{H} + \mathbf{X}_b^{'}\Lambda_v^{-1}\mathbf{X}_b), \tag{38}$$

$$\hat{\boldsymbol{b}} = \mathbf{K}_b^{-1}(\mathbf{H}^{'}\Sigma_b^{-1}\mathbf{H}\delta_b + \mathbf{X}_b^{'}\Lambda_v^{-1}\tilde{\pi}). \tag{39}$$

As mentioned above, a Metropolis-Hasting step is taken to draw $\boldsymbol{b}$. First, candidate draws are obtain from distribution of equation (37) and then they are accepted or reject via the Metropolis-Hasting step.

Draw $p(\boldsymbol{d}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta)$,

To sample from this conditional posterior, we first need to rewrite (2) and (5) into

$$z = \mathbf{X}_d\boldsymbol{d} + \boldsymbol{H}_\psi\epsilon_z, \quad \epsilon_z \sim N(0, \sigma_w^2\mathbf{I}_T), \tag{40}$$

$$\mathbf{H}_\rho\boldsymbol{d} = \tilde{\delta}_d + \epsilon_d, \quad \epsilon_d \sim N(0, \Sigma_d), \tag{41}$$

where $\tilde{\delta}_d = (\mu_{d,0}, \mu_{d,1}, (1-\rho_{d,0})\mu_{d,0}, (1-\rho_{d,1})\mu_{d,1}, \ldots, (1-\rho_{d,0})\mu_{d,0}, (1-\rho_{d,1})\mu_{d,1})'$, $\Sigma_d = diag(\frac{\sigma_{d,0}^2}{(1-\rho_{d,0}^2)}, \frac{\sigma_{d,1}^2}{(1-\rho_{d,1}^2)}, \sigma_{d,0}^2, \sigma_{d,1}^2, \ldots, \sigma_{d,0}^2, \sigma_{d,1}^2)'$,

$$\mathbf{X}_d = \begin{bmatrix} 1 & \pi_1^* & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \pi_2^* & 0 & \cdots & 0 \\ \vdots & & & \ddots & \ddots & & \vdots \\ 0 & 0 & 0 & 0 & 0 & 1 & \pi_T^* \end{bmatrix}, \tag{42}$$

and

$$\mathbf{H}_\rho = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 1 & 0 & 0 & 0 & \cdots & 0 \\ -\rho_{d,0} & 0 & 1 & 0 & 0 & \cdots & 0 \\ 0 & -\rho_{d,1} & 0 & 1 & \ddots & & 0 \\ 0 & 0 & \ddots & 0 & \ddots & \ddots & \\ \vdots & & \ddots & -\rho_{d,0} & \ddots & \ddots & 0 \\ 0 & 0 & 0 & 0 & -\rho_{d,1} & 0 & 1 \end{bmatrix}. \tag{43}$$

Combining (40) and (41), we can derive the conditional posterior

$$\log p(\boldsymbol{d}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta) \propto -\frac{1}{2\sigma_w^2}(z-\mathbf{X}_d\boldsymbol{d})'(\mathbf{H}_\psi\mathbf{H}_\psi^{'})^{-1}(z-\mathbf{X}_d\boldsymbol{d})-\frac{1}{2}(\boldsymbol{d}-\delta_d)'\mathbf{H}_\rho^{'}\Sigma_d^{-1}\mathbf{H}_\rho(\boldsymbol{d}-\delta_d), \tag{44}$$

where $\delta_d = \mathbf{H}_\rho^{-1}\tilde{\delta}_d$. Thus from (44), the conditional posterior is

$$(\boldsymbol{d}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta) \sim N(\hat{\boldsymbol{d}}, \mathbf{K}_d^{-1}), \tag{45}$$

where

$$\mathbf{K}_d = (\mathbf{H}_\rho^{'}\Sigma_d^{-1}\mathbf{H}_\rho + \frac{1}{\sigma_w^2}\tilde{\mathbf{X}}_d^{'}\tilde{\mathbf{X}}_d), \tag{46}$$

$$\hat{\boldsymbol{d}} = \mathbf{K}_d^{-1}(\mathbf{H}_\rho^{'}\Sigma_d^{-1}\tilde{\delta}_d + \frac{1}{\sigma_w^2}\tilde{\mathbf{X}}_d^{'}\mathbf{H}_\psi^{-1}z), \tag{47}$$

where $\tilde{\mathbf{X}}_d = \mathbf{H}_\psi^{-1}\mathbf{X}_d$. Again, we construct a band approximation of $\tilde{\mathbf{X}}_d$ by replacing all elements less than 10^{-6} with zero. Similar to step 1, the precision sampler approach of Chan and Jeliazkov (2009) is used to sample $\hat{\boldsymbol{d}}$.

Draw $p(\boldsymbol{h}_v, \boldsymbol{h}_n|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \theta)$

To draw the stochastic volatilizes of $\boldsymbol{h}_v, \boldsymbol{h}_n$, we implement the precision sampler technique by Chan and Hsiao (2014) and follow their procedure whereby they implement the Kim, Shepherd and Chib (1998) auxiliary mixture sampler in approximating the $\log - \chi_1^2$ distribution using a seven component Gaussian mixture density with fixed parameters. For more information, please see Chan and Hsiao (2014).

Draw $p(\mu_{d,0}, \mu_{d,1}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\mu_{d,0},\mu_{d,1}\}})$ **and** $p(\sigma_{d,0}^2, \sigma_{d,1}^2|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma_{d,0}^2,\sigma_{d,1}^2\}})$

Both these conditional posteriors are standard:

$$(\mu_{d,i}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\mu_{d,0},\mu_{d,1}\}}) \sim N(\hat{\mu}_{d,i}, \mathbf{K}_{d,i}^{-1}), \tag{48}$$

$$(\sigma_{d,i}^2|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma_{d,0}^2,\sigma_{d,1}^2\}}) \sim IG(\nu_{d,i} + \frac{T}{2}, \tilde{S}_{d,i}), \tag{49}$$

where $\mathbf{K}_{d,i} = \frac{1}{V_\mu} + \frac{(1-\rho_{d,i}^2)}{\sigma_{d,i}^2} + (T-1)\frac{(1-\rho_{d,i})^2}{\sigma_{d,i}^2}$, $\hat{\mu}_{d,i} = \mathbf{K}_{d,i}^{-1}(\frac{a_i}{V_\mu} + \frac{(1-\rho_{d,i}^2)d_{i,1}}{\sigma_{d,i}^2} + \sum_{t=2}^T \frac{(1-\rho_{d,i})(d_{i,t}-\rho_{d,i}d_{i,t-1})}{\sigma_{d,i}^2})$ and $\tilde{S}_{d,i} = S_{d,i} + \frac{((1-\rho_{d,i}^2)(d_{i,1}-\mu_{d,i})^2 + \sum_{t=2}^T(d_{i,t}-\mu_{d,i}(1-\rho_{d,i})-\rho_{d,i}d_{i,t-1})^2}{}$

Draw $p(\rho_{d,0}, \rho_{d,1}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\rho_{d,0},\rho_{d,1}\}})$

$$p(\rho_{d,i}|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\rho_{d,0},\rho_{d,1}\}}) \propto p(\rho_{d,i}) g_{\rho_{d,i}}(\rho_{d,i}) e^{-\frac{1}{2}\sum_{t=2}^{T}(d_{i,t}-\mu_{d,i}-\rho_{d,i}(d_{i,t-1}-\mu_{d,i}))^2}, \tag{50}$$

where $p(\rho_{d,i})$ is the truncated normal prior for $\rho_{d,i}$ and $g_{\rho_{d,i}}(\rho_{d,i}) = (1-\rho_{d,i}^2)^{\frac{1}{2}} \exp(-\frac{1}{2\sigma_{d,i}^2}(1-\rho_{d,i}^2)(d_{i,1}-\mu_{d,i})^2)$. This conditional density is non-standard, which means a Metropolis-Hasting step must be undertaken to draw $\rho_{d,i}$. We follow Chan et al. (2017) where they implement an independence chain Metropolis-Hasting step with a proposal distribution $N(\hat{\rho}_{d,i}, K_{\rho_{d,i}}^{-1})$, where $K_{\rho_{d,i}} = (\frac{1}{V_\rho} + \frac{X'_{\rho_{d,i}} X_{\rho_{d,i}}}{\sigma_{d,i}^2})$ and $\hat{\rho}_{d,i} = K_{\rho_{d,i}}^{-1}(\frac{a_2}{V_\rho} + \frac{X'_{\rho_{d,i}} y_{\rho_{d,i}}}{\sigma_{d,i}^2})$, with $X_{\rho_{d,i}} = (d_{i,1}-\mu_{d,i}, \ldots, d_{i,t-1}-\mu_{d,i})'$ and $y_{\rho_{d,i}} = (d_{i,2}-\mu_{d,i}, \ldots, d_{i,T}-\mu_{d,i})'$.

Draw $p(\psi|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\psi\}})$

To draw ψ, we follow Chan (2013) by implementing an independence chain Metropolis-Hasting step. Specifically, we evaluate the log-density below using band matrix routines, where we maximize it numerically to obtain the mode and negative Hessian, denoted as $\hat{\psi}$ and K_ψ. Then, we generate candidate draws from the $N(\hat{\psi}, K_\psi^{-1})$ distribution.

$$\log p(\psi|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\psi\}}) \propto \log p(z|\pi^*, \boldsymbol{d}, \sigma_w^2) + \log p(\psi), \tag{51}$$

$$\propto -\frac{1}{2\sigma_w^2}(z - d_0 - \mathbf{X}_{\pi^*}\pi^*)'(\mathbf{H}_\psi \mathbf{H}_\psi')^{-1}(z - d_0 - \mathbf{X}_{\pi^*}\pi^*) + \log p(\psi), \tag{52}$$

where $\log p(\psi)$ is the prior density of ψ.

Draw $p(\sigma_b^2, \sigma_w^2, \sigma_{h_v}^2, \sigma_{h_n}^2|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma_b^2,\sigma_z^2,\sigma_{h_v}^2,\sigma_{h_n}^2\}})$

All these variance parameters are conditionally independent given the data and states. $\sigma_z^2, \sigma_{h_v}^2, \sigma_{h_n}^2$ all follow standard inverse-Gamma distributions

$$(\sigma_w^2|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma_b^2,\sigma_z^2,\sigma_{h_v}^2,\sigma_{h_n}^2\}}) \sim IG(\nu_{\sigma_w^2} + \frac{T}{2}, S_{\sigma_w^2} + \frac{1}{2}\sum_{t=1}^{T}\tilde{\epsilon}_{z,t}^2), \tag{53}$$

$$(\sigma_{h_i}^2|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma_b^2,\sigma_z^2,\sigma_{h_v}^2,\sigma_{h_n}^2\}}) \sim IG(\nu_{\sigma_{h_i}^2} + \frac{T-1}{2}, S_{\sigma_{h_i}^2} + \frac{1}{2}\sum_{t=2}^{T}(h_{i,t} - h_{i,t-1})^2), \quad i = v, n, \tag{54}$$

where the elements of $\tilde{\epsilon}_z$ can be computed as $\tilde{\epsilon}_z = \mathbf{H}_\psi^{-1}(z - \mathbf{X}_d \boldsymbol{d})$. To draw σ_b^2, an Metropolis-Hasting step has to be undertaken since the conditional density is non-standard given

$$\log(\sigma_b^2|Data, \pi^*, \boldsymbol{b}, \boldsymbol{d}, \boldsymbol{h}_v, \boldsymbol{h}_n, \theta_{-\{\sigma_b^2, \sigma_z^2, \sigma_{h_v}^2, \sigma_{h_n}^2\}}) \propto -(\nu_{\sigma_b^2} + 1)\log -\frac{S_{\sigma_b^2}}{\sigma_b^2} - \frac{T-1}{2}\log \sigma_b^2 \ldots$$

$$\ldots - \frac{1}{2\sigma_b^2}\sum_{t=2}^{T}(b_t - b_{t-1})^2 + g_b(b, \sigma_b^2). \quad (55)$$

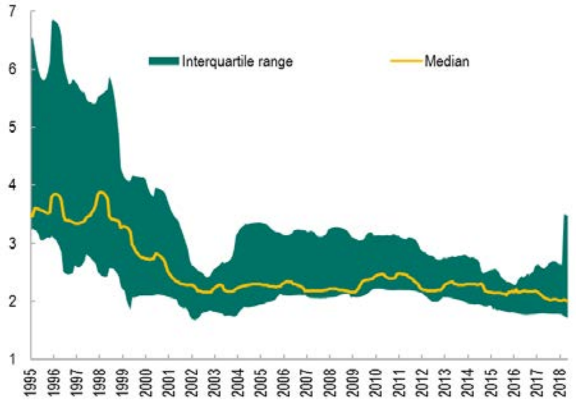
To implement the Metropolis-Hasting step, we first draw from a proposal density

$$IG(\nu_{\sigma_b^2} + \frac{T-1}{2}, S_{\sigma_b^2} + \frac{1}{2}\sum_{t=2}^{T}(b_t - b_{t-1})^2). \quad (56)$$

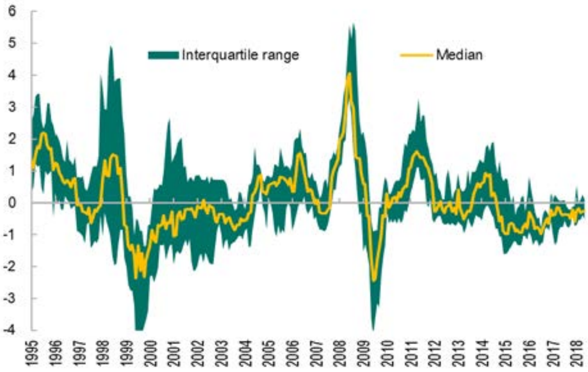
A. Asian trend IMF WP: regional panels

Figure 1. Asian headline Inflation decomposition

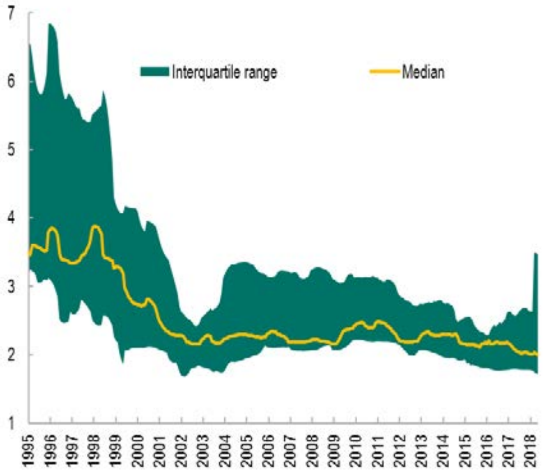
A. Trend inflation (All countries)
(Percent)



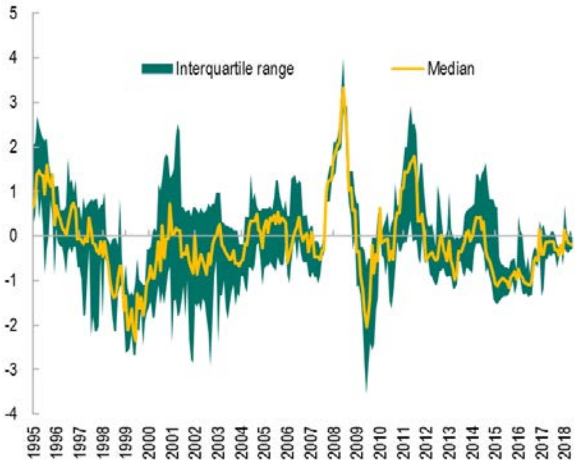
B. Transitory inflation (All countries)
(Percent)



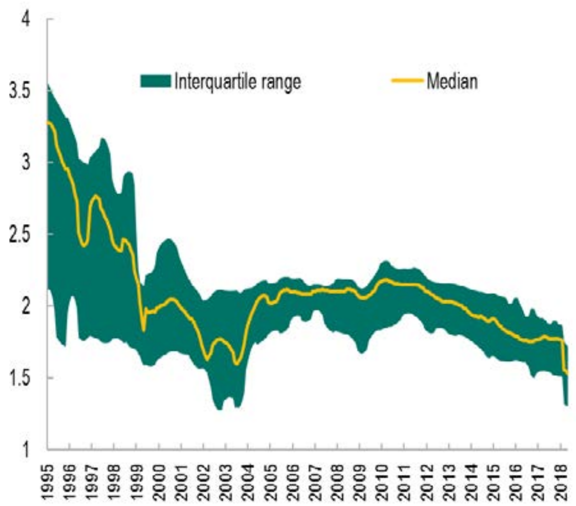
C. Trend inflation (Advanced economies)
(Percent)



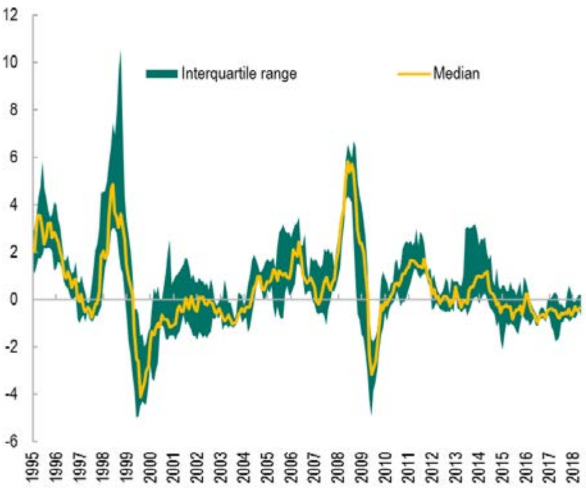
D. Transitory inflation (Advanced economies)
(Percent)



E. Trend inflation (Emerging economies)
(Percent)



F. Transitory inflation (Emerging economies)
(Percent)



Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). The panel shows the median (solid yellow line) and the interquartile range of trend and transitory inflation components (green shadowed area) for twelve Asian economies, six advanced (Australia, New Zealand, Japan, South Korea, Hong Kong SAR and Taiwan) and six emerging economies (India, Indonesia, Malaysia, Philippines, Singapore and Thailand).
Source: Haver analytics and authors' calculations.

Table 1. Forecast performance for headline inflation
Core and Trend inflation measures, two years ahead

	Australia	Hong Kong SAR	Japan	Korea	New Zealand	Taiwan POC	China	India	Indonesia	Malaysia	Philippines	Thailand
Full sample (1995-2018)												
Core inflation	1.55	4.02	1.44	1.81	1.31	1.88	2.55	4.01	3.50	1.59	2.47	2.82
Trend inflation	1.22	3.77	1.32	1.54	1.26	1.73	1.70	3.55	3.95	1.03	2.07	2.42
Post-GFC (2010-2018)												
Core inflation	0.91	2.43	1.71	1.17	1.27	1.36	2.61	2.62	1.97	1.59	1.54	1.84
Trend inflation	0.68	1.85	1.29	1.07	1.30	1.13	1.27	3.71	1.75	0.98	1.26	1.70

Notes: the table report the Root-Mean Square Forecast Error (RMSFE) for two alternative measures of underlying inflation, the standard Core inflation (CPI excluding food and energy), and trend inflation (posterior mean) based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). The RMSFE is calculated for the forecast of headline inflation over a horizon of two years. The sample is generally January 1995-June 2018, but the core inflation measures follow the sample published in the country's official statistics, and the trend inflation measure is also adjusted accordingly.
Source: Haver analytics and authors' calculations.

Table 2. Inflation decomposition: basic statistics

A. Headline inflation

Inflation	Mean	Median	St. Deviation	Skewness	Kurtosis	Min.	Max.	Range
Australia	2.56	2.48	1.30	0.61	0.94	-0.45	6.13	6.57
Hong Kong SAR	2.01	2.29	3.45	-0.15	-0.42	-6.10	10.31	16.41
Japan	0.14	-0.10	1.03	1.02	1.73	-2.52	3.74	6.25
Korea	2.95	2.69	1.68	0.95	1.46	0.17	9.55	9.38
New Zealand	2.06	1.87	1.24	0.34	-0.19	-0.60	5.28	5.87
Taiwan POC	1.21	1.11	1.48	0.44	0.19	-2.33	5.81	8.14
China	2.84	1.88	4.00	2.55	8.83	-2.20	24.10	26.30
India	6.82	6.07	3.09	0.74	0.99	0.00	19.67	19.67
Indonesia	9.92	6.65	12.97	4.02	16.99	-1.16	82.39	83.56
Malaysia	2.57	2.50	1.49	0.67	3.26	-2.48	8.52	11.00
Philippines	4.80	4.41	2.33	0.59	-0.28	0.35	10.70	10.34
Thailand	2.76	2.43	2.55	0.52	0.42	-4.35	10.53	14.88

B. Core inflation (excluding food and energy)

Core inflation	Mean	Median	St. Deviation	Skewness	Kurtosis	Minimum	Maximum	Range
Australia	2.53	2.40	0.95	1.52	3.26	0.73	6.75	6.02
Hong Kong SAR	1.73	1.89	3.89	0.00	-0.29	-7.86	10.88	18.74
Japan	-0.06	-0.20	0.87	1.14	1.19	-1.70	2.42	4.12
Korea	2.78	2.56	1.39	0.78	0.79	-0.35	7.44	7.79
New Zealand	1.78	1.72	0.71	0.34	-0.53	0.34	3.58	3.25
Taiwan POC	0.74	0.64	1.07	0.95	2.13	-2.26	5.05	7.31
China	1.25	1.50	0.91	-1.62	2.48	-1.60	2.50	4.10
India	6.67	6.61	2.63	0.30	-0.19	0.87	14.69	13.82
Indonesia	5.51	4.93	1.80	0.88	0.01	2.98	10.20	7.23
Malaysia	2.48	2.44	0.50	1.42	1.22	1.96	3.57	1.60
Philippines	3.82	3.49	1.48	0.58	-0.65	1.40	7.25	5.85
Thailand	1.96	1.24	1.94	1.49	1.60	-1.19	8.49	9.68

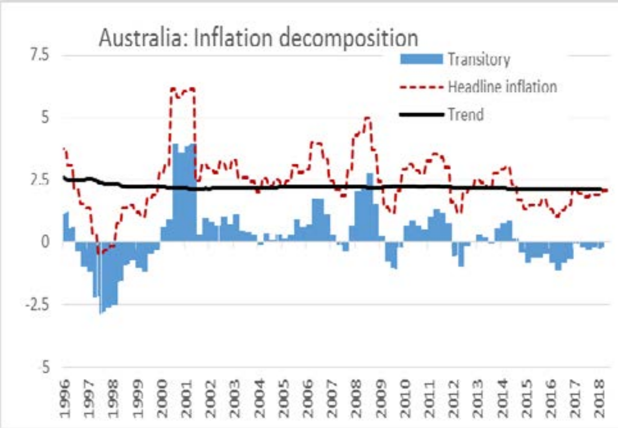
C. Trend inflation

Trend Inflation	Mean	Median	St. Deviation	Skewness	Kurtosis	Minimum	Maximum	Range
Australia	2.25	2.19	0.19	3.68	15.25	2.12	3.33	1.21
Hong Kong	2.73	2.18	1.48	1.80	1.86	1.16	7.09	5.93
Japan	0.93	0.96	0.32	-0.16	2.41	-0.07	1.93	2.00
Korea	2.39	2.27	0.47	0.72	-0.26	1.66	3.63	1.97
New Zealand	1.83	1.88	0.21	-0.52	-1.06	1.37	2.11	0.73
Taiwan	1.89	1.75	0.48	1.70	1.93	1.27	3.32	2.04
China	3.39	2.87	1.56	2.10	3.40	1.87	8.24	6.37
India	4.94	4.60	1.04	1.83	2.68	4.06	8.89	4.83
Indonesia	4.90	4.47	0.91	0.90	-0.48	3.89	6.92	3.03
Malaysia	2.45	2.32	0.51	1.09	0.95	1.66	4.04	2.38
Philippines	4.19	4.04	1.18	0.12	-0.66	1.83	6.84	5.01
Thailand	2.71	2.52	0.53	1.00	-0.18	1.85	3.91	2.07

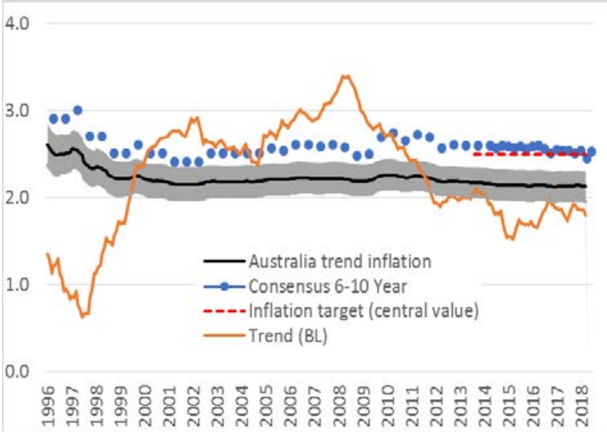
Notes: the tables report some basic statistics for headline inflation, standard core inflation (CPI excluding food and energy), and trend inflation (posterior mean) based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). The sample is generally January 1995-June 2018, but core inflation measures follow the sample published in the country's official statistics.
Source: Haver analytics and authors' calculations.

Figure 2. Inflation analysis: Australia

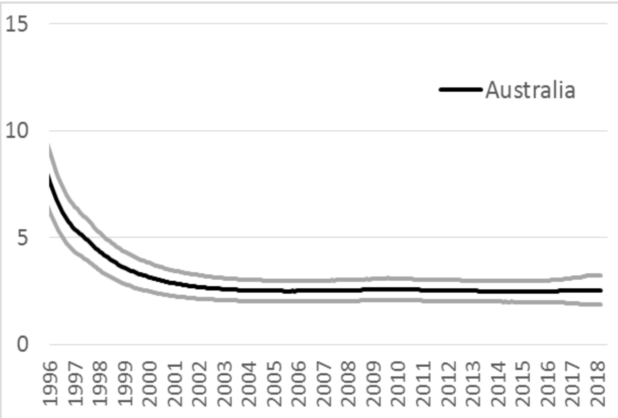
A. Headline inflation decomposition: trend and transitory components
(Percent)



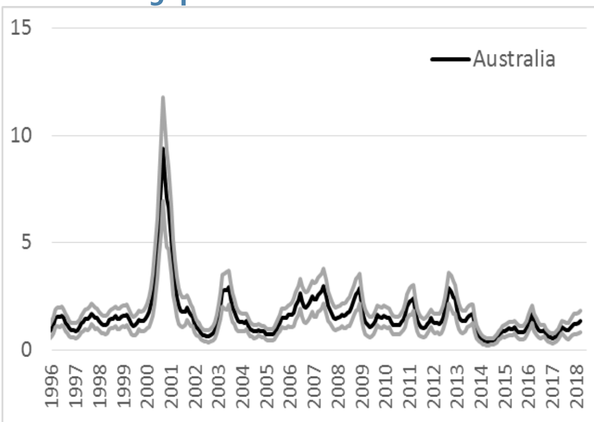
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



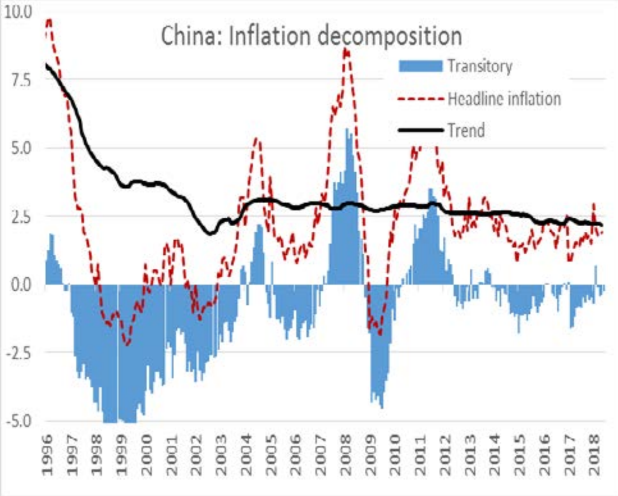
D. Inflation gap shocks: standard deviation



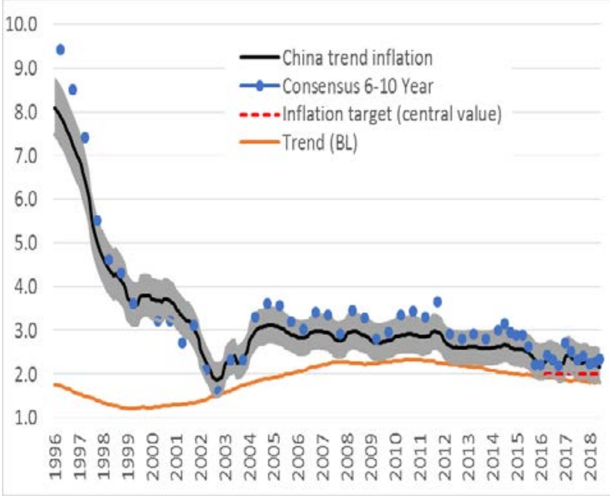
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 3. Inflation analysis: China

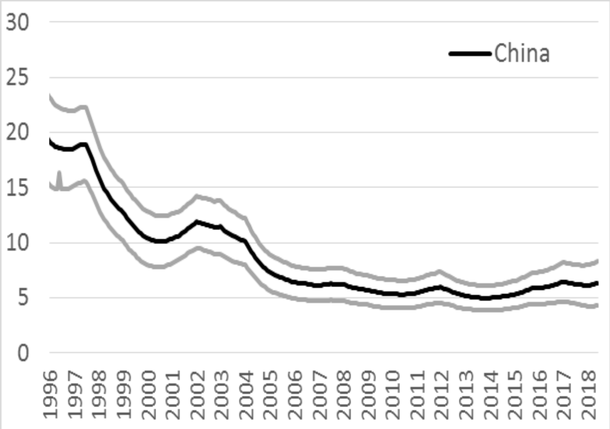
A. Headline inflation decomposition: trend and transitory components
(Percent)



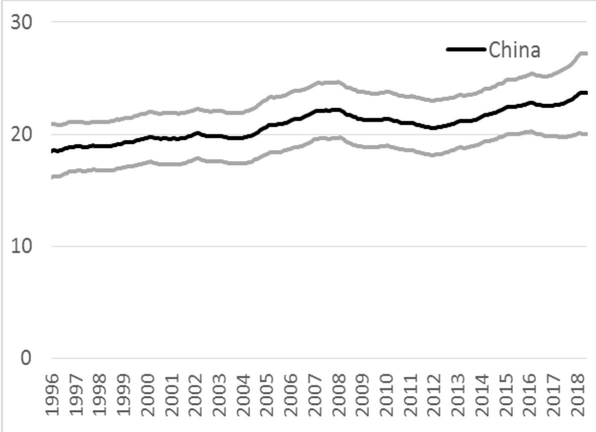
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



D. Inflation gap shocks: standard deviation

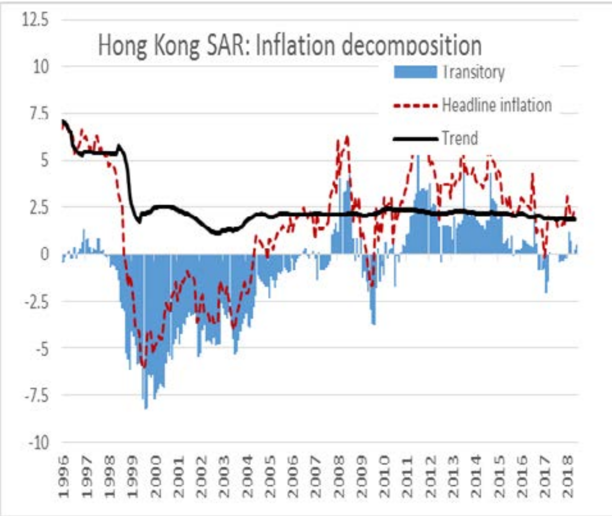


Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 4. Inflation analysis: Hong Kong SAR

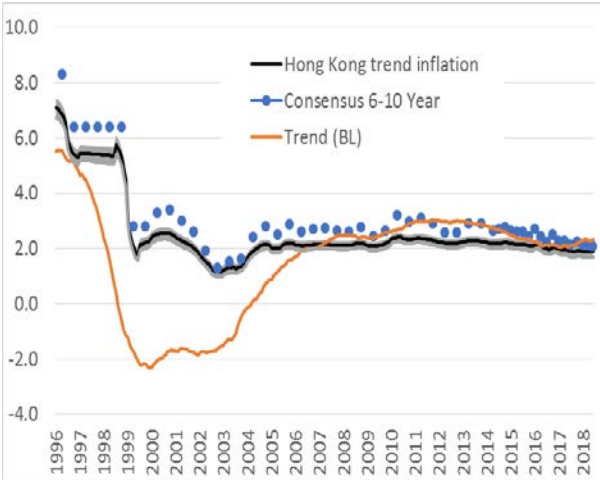
A. Headline inflation decomposition: trend (RHS scale) and transitory components

(Percent)

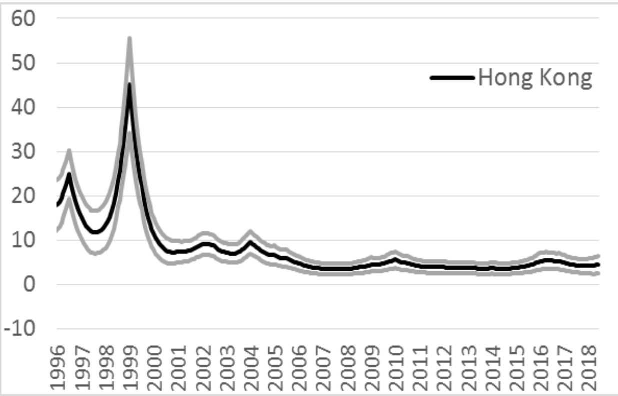


B. Trend inflation

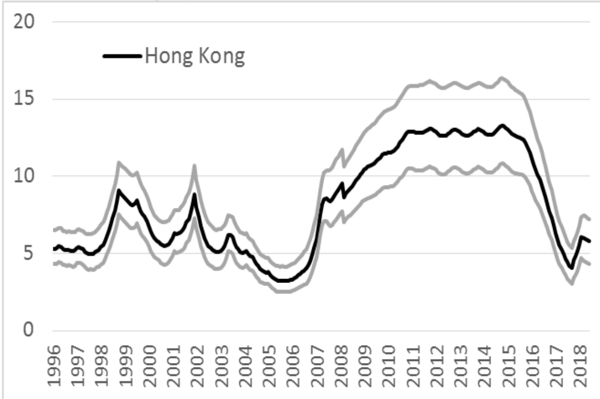
(Percent)



C. Trend inflation shock: standard deviation



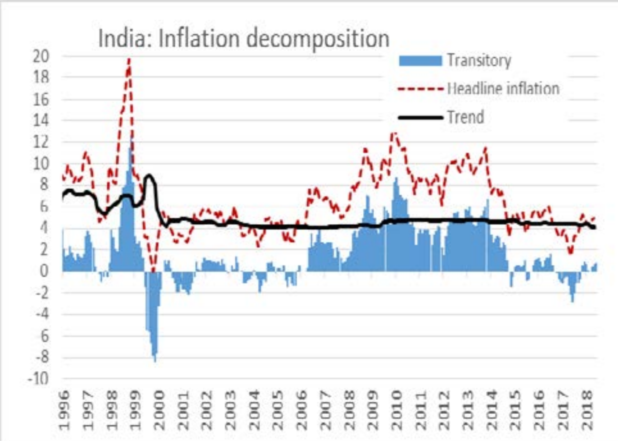
D. Inflation gap shocks: standard deviation



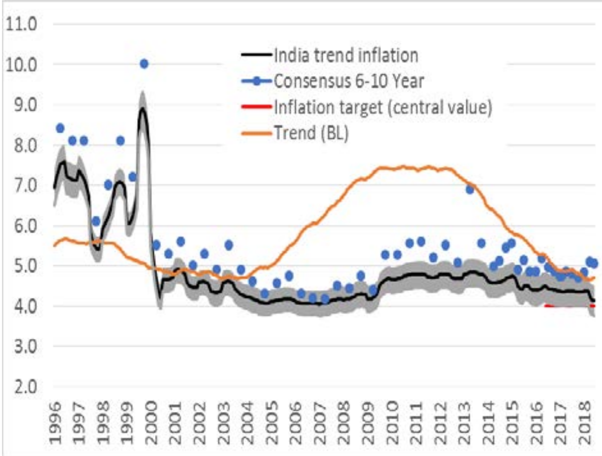
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 5. Inflation analysis: India

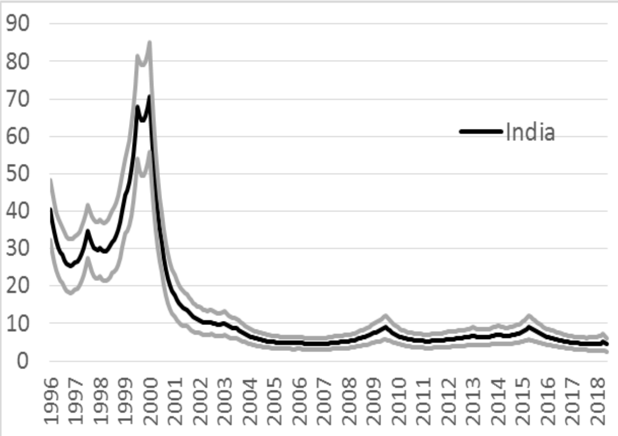
A. Headline inflation decomposition: trend and transitory components
(Percent)



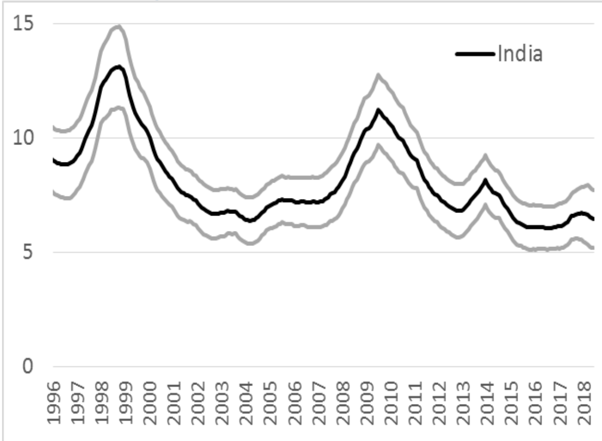
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



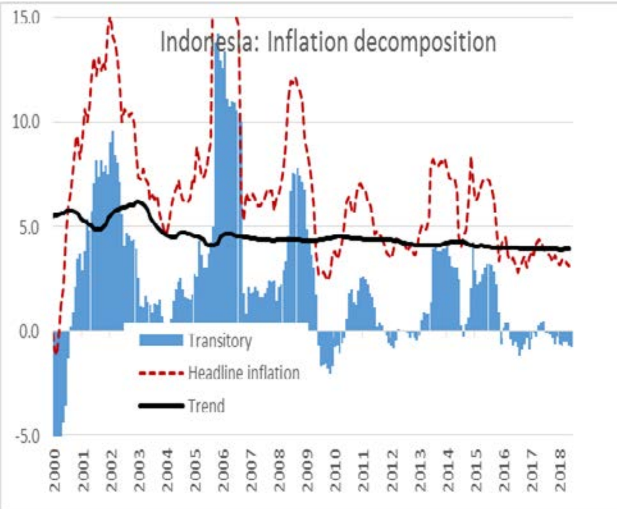
D. Inflation gap shocks: standard deviation



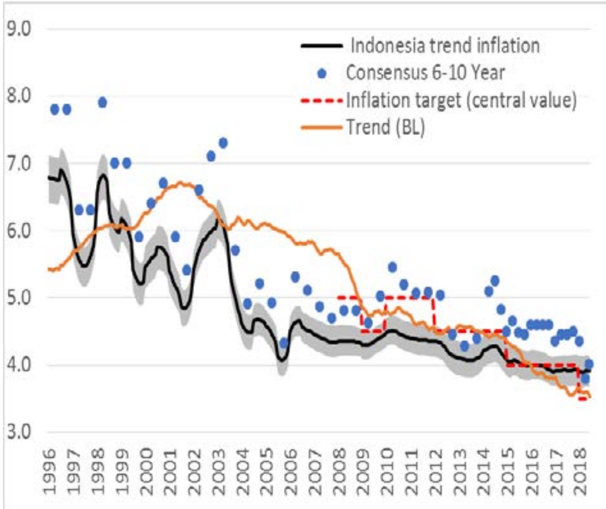
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors’ calculations

Figure 6. Inflation analysis: Indonesia

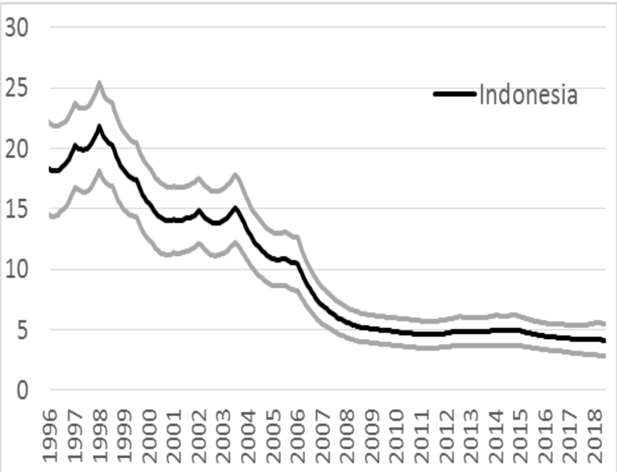
A. Headline inflation decomposition: trend and transitory components
(Percent)



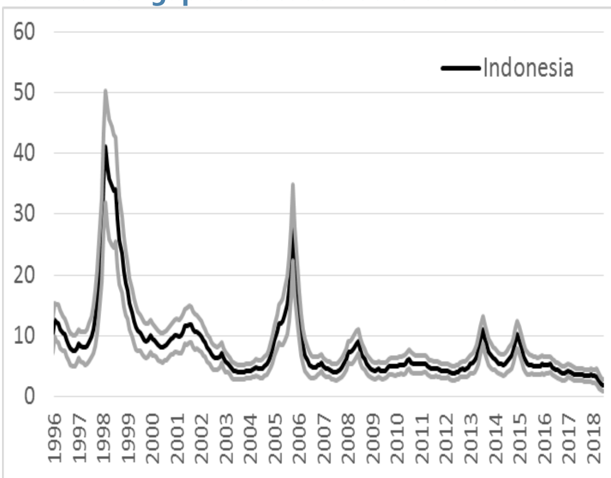
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



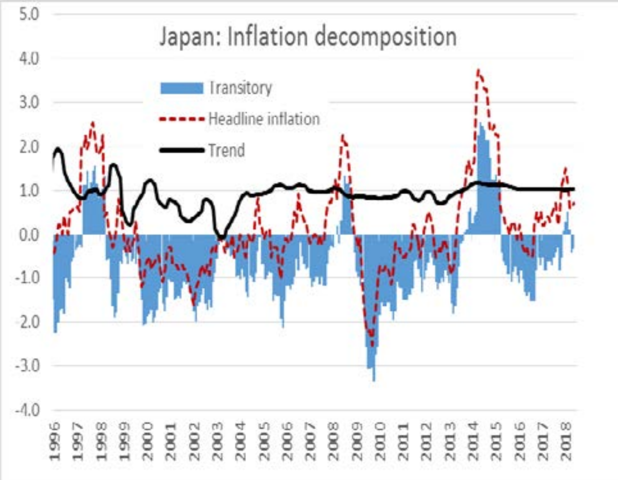
D. Inflation gap shocks: standard deviation



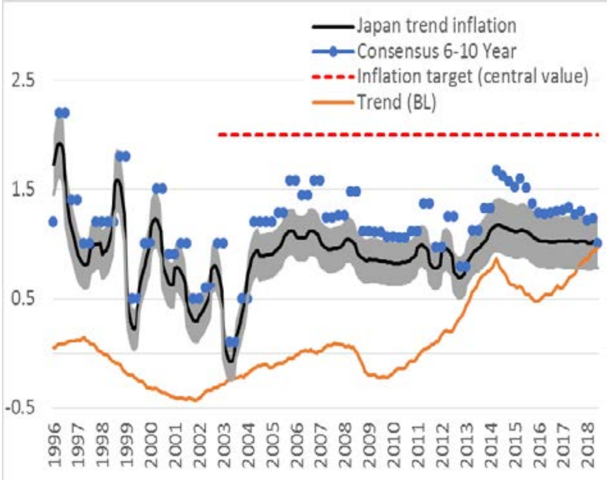
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16^{th} and 84^{th} quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 7. Inflation analysis: Japan

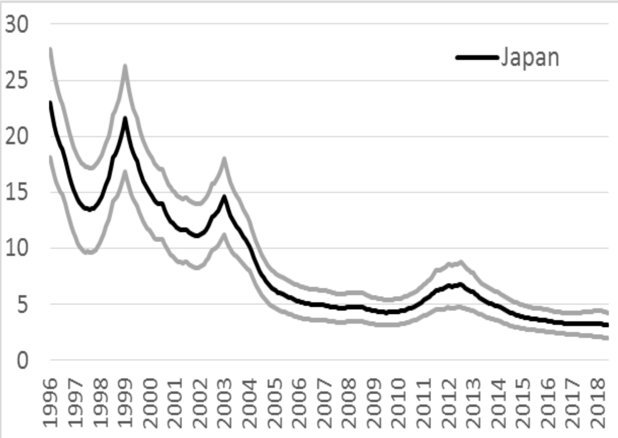
A. Headline inflation decomposition: trend (RHS scale) and transitory components
(Percent)



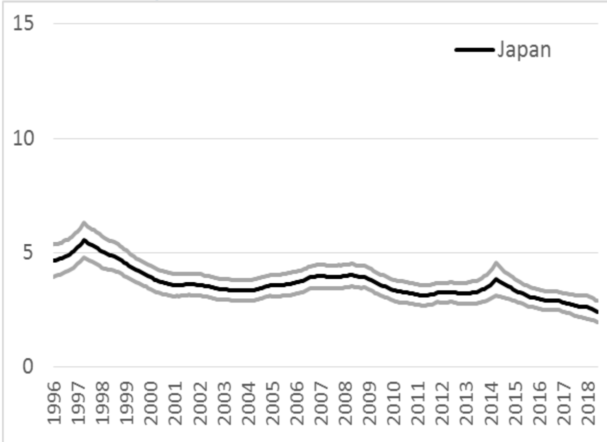
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



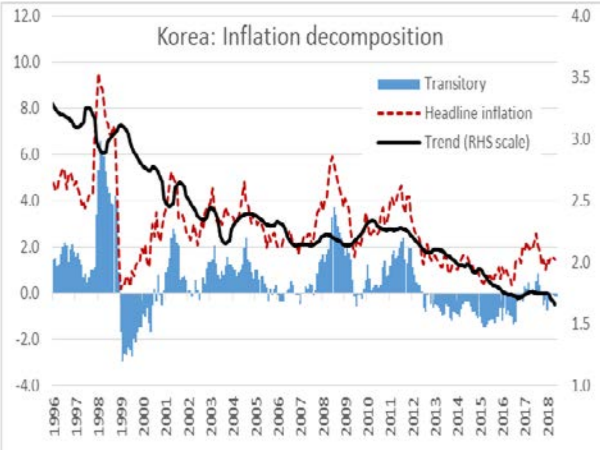
D. Inflation gap shocks: standard deviation



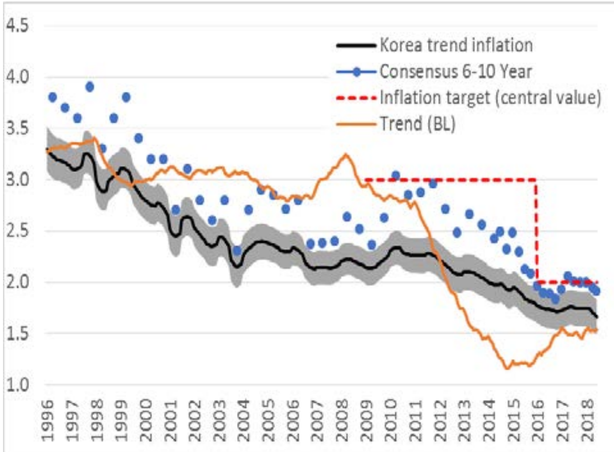
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 8. Inflation analysis: South Korea

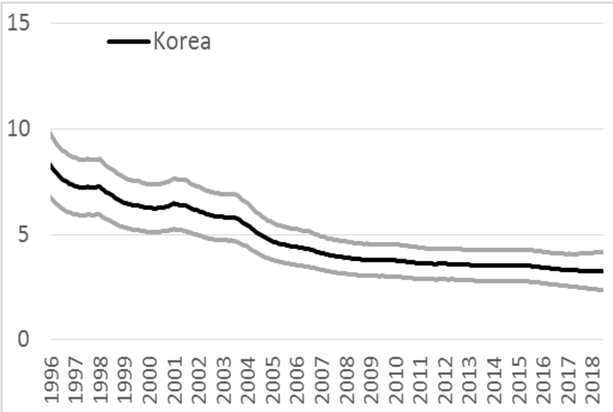
A. Headline inflation decomposition: trend (RHS scale) and transitory components
(Percent)



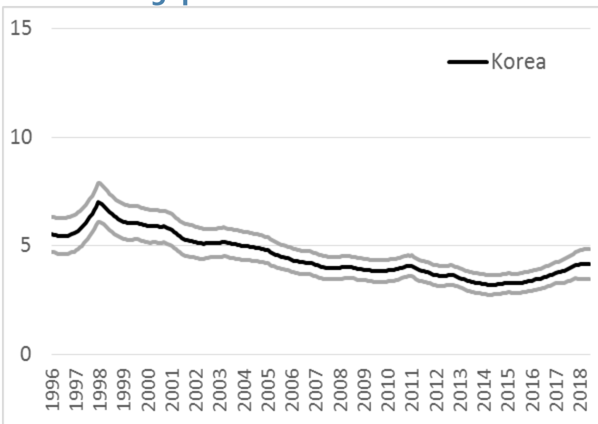
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



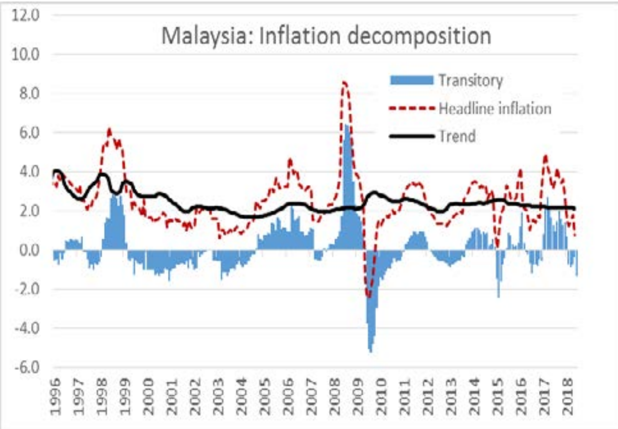
D. Inflation gap shocks: standard deviation



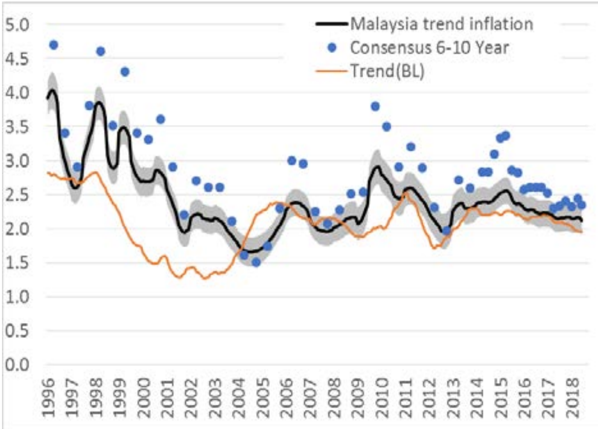
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 9. Inflation analysis: Malaysia

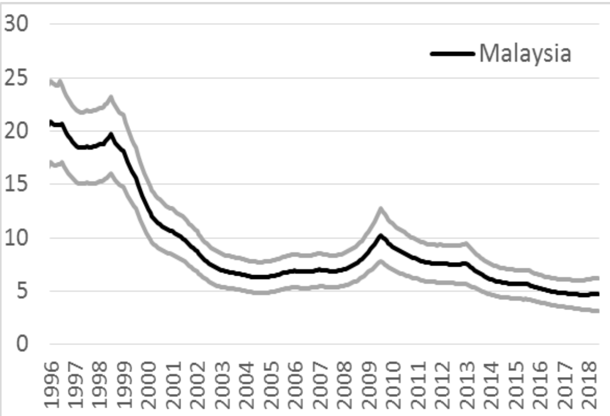
A. Headline inflation decomposition: trend and transitory components
(Percent)



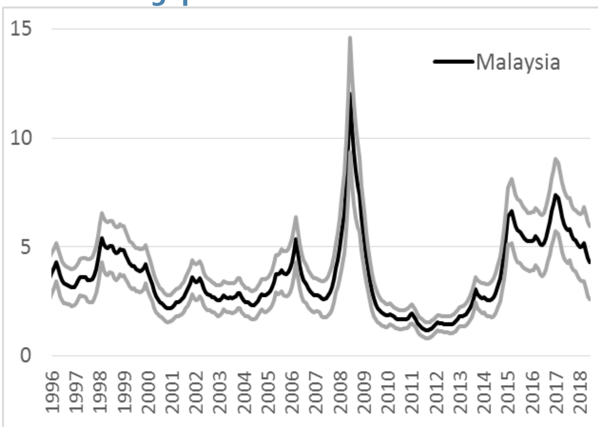
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



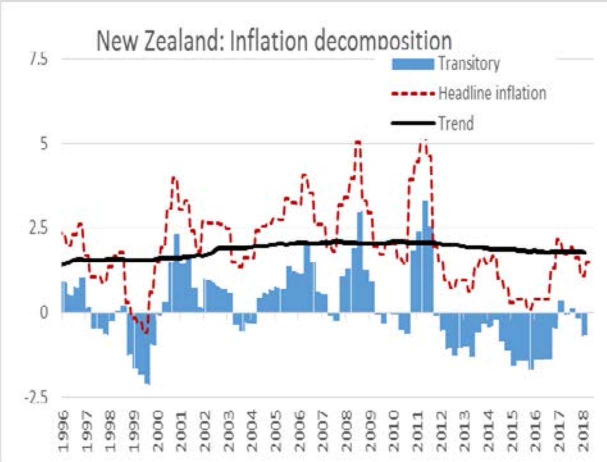
D. Inflation gap shocks: standard deviation



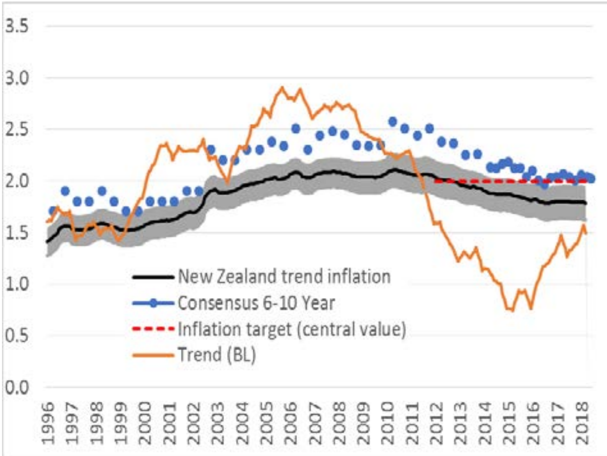
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors’ calculations

Figure 10. Inflation analysis: New Zealand

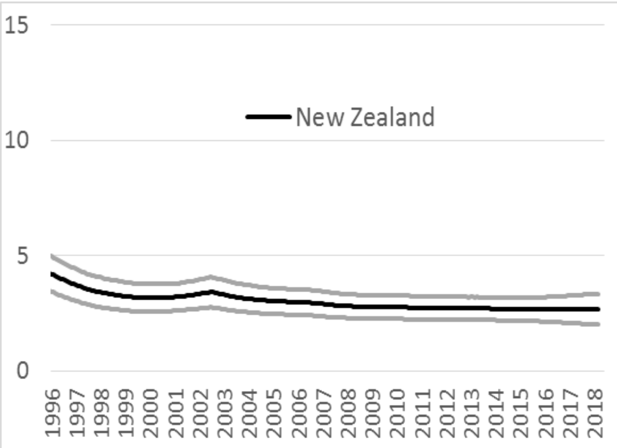
A. Headline inflation decomposition: trend and transitory components
(Percent)



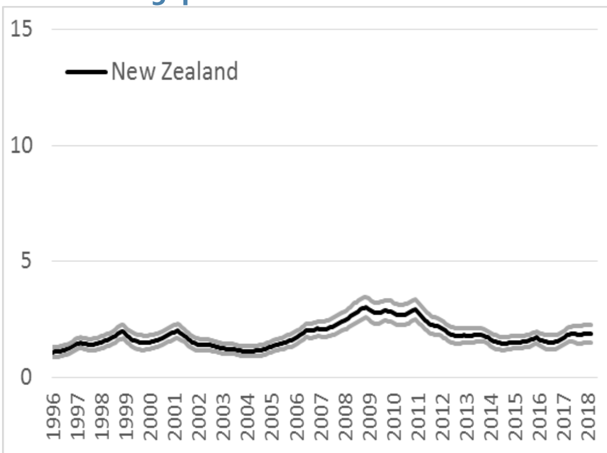
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



D. Inflation gap shocks: standard deviation

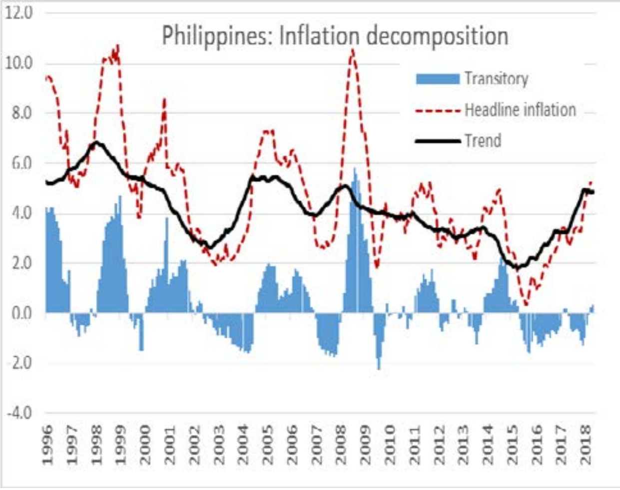


Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations

Figure 11. Inflation analysis: Philippines

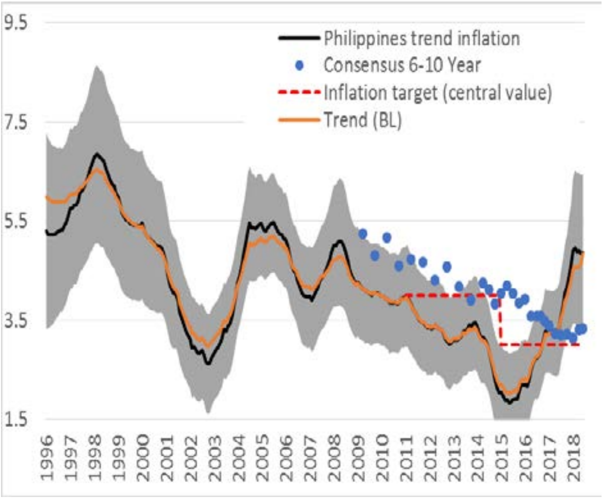
A. Headline inflation decomposition: trend and transitory components

(Percent)



B. Trend inflation

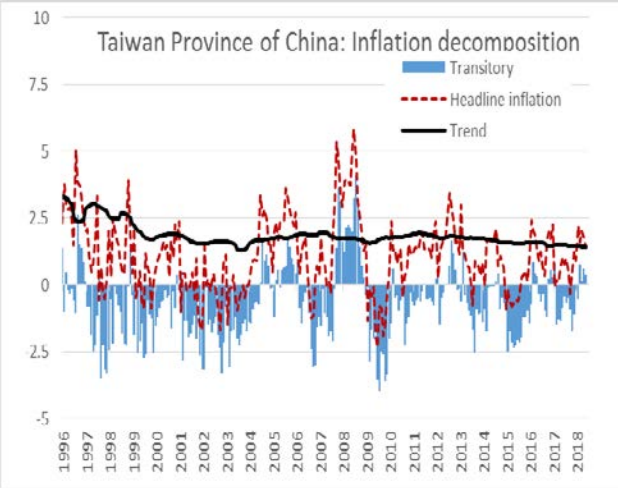
(Percent)



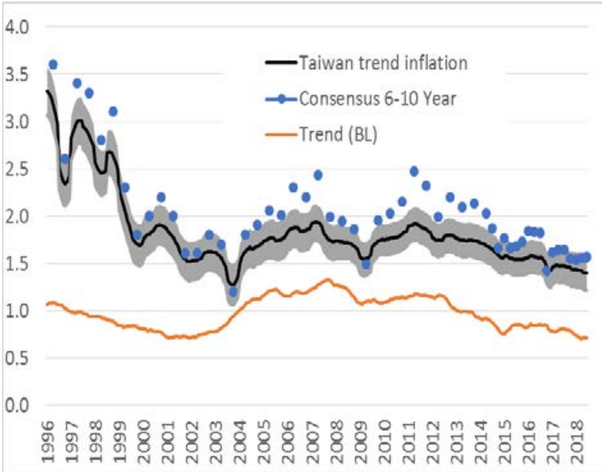
Notes: given the limited availability of of long-term survey measures of inflation expectations (see Panel B, blue dots), trend inflation estimates for the Philippines are based on Chan et al (2013). Such model specification does not allow for stochastic volatility in the trend inflation estimates, and therefore the volatility of its shocks is not reported here, in contrast to the rest of the country panels in our sample. Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots).
Source: Haver analytics and authors' calculations

Figure 12. Inflation analysis: Taiwan

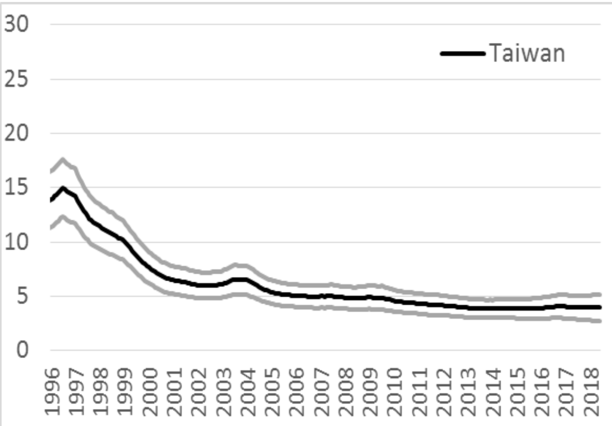
A. Headline inflation decomposition: trend (RHS scale) and transitory components
(Percent)



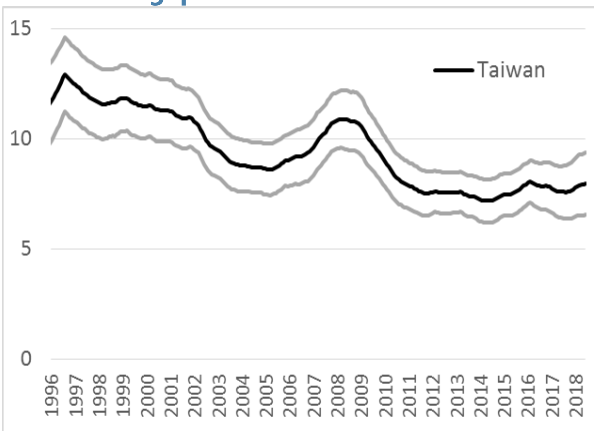
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



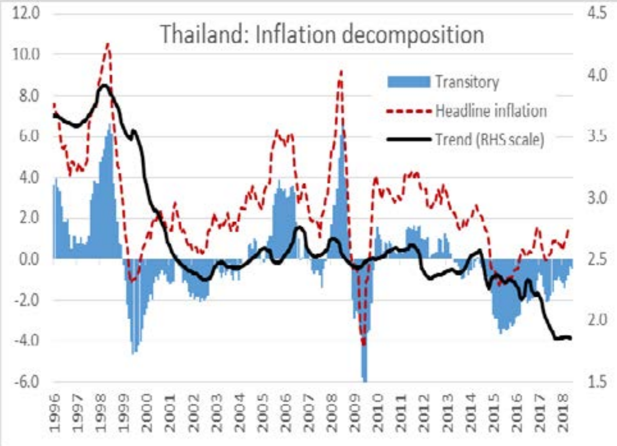
D. Inflation gap shocks: standard deviation



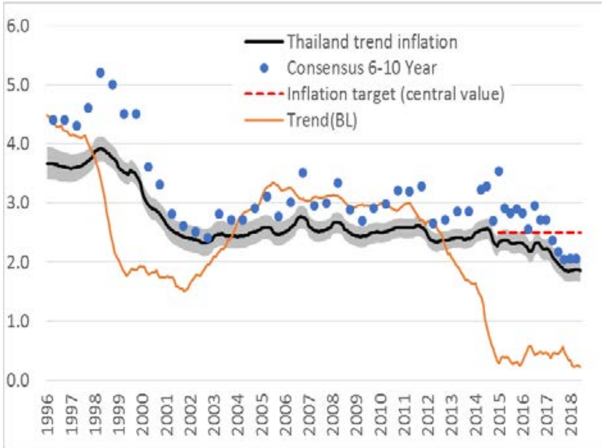
Notes: analysis of headline inflation dynamics based on our benchmark model specification (UC-SUR). Panel B also includes trend inflation estimates based on the alternative model (UC) using only backward-looking (historical inflation realizations) information, and the level of the inflation target or central value of the target range announced by the central bank. Solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution. Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively.

Figure 13. Inflation analysis: Thailand

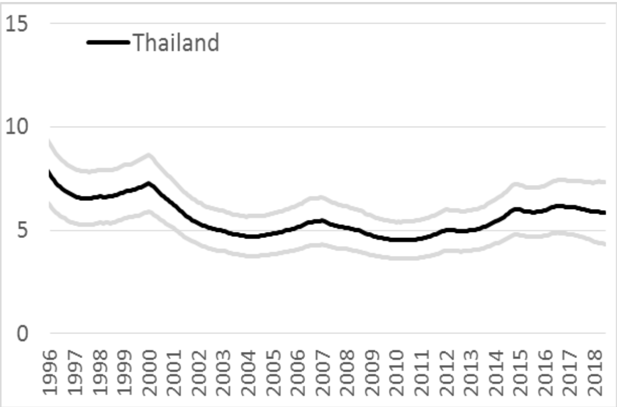
A. Headline inflation decomposition: trend (RHS scale) and transitory components
(Percent)



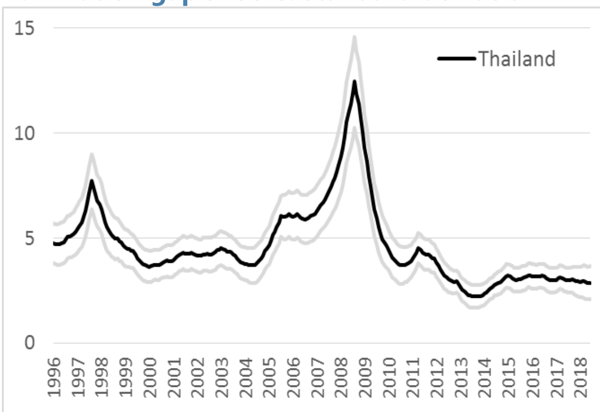
B. Trend inflation
(Percent)



C. Trend inflation shock: standard deviation



D. Inflation gap shocks: standard deviation



Notes: analysis of headline inflation dynamics based on our benchmark model specification (UCSV-SUR, see Section 4 for model details). Panel A reports the decomposition of inflation into a trend (or persistent) component and the transitory (or inflation gap) component. Panel B also includes trend inflation estimates based on the benchmark model specification (solid black line, with shadowed area reflecting 16th and 84th quantiles), trend inflation estimates using an alternative model (UCSV-BL, orange line) using only backward-looking information (historical inflation realizations), the level of the inflation target (or central value of the target range, red discontinued line) announced by the central bank, and survey (long-term) inflation expectations from Consensus Forecasts (blue dots). Panels C and D show the estimated standard deviation of the volatility of inflation gap and trend inflation respectively, with solid black lines show posterior mean estimates, and the thinner lines and shadowed area show the 66 percent confidence sets from the model´s posterior distribution.
Source: Haver analytics and authors' calculations.

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