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Inflation volatility in small and large advanced open economies

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ABSTRACT

Inflation volatility is clearly important for structural analysis, forecasting and policy purposes, yet it is often overlooked in the literature. This paper compares inflation volatility among advanced open economies with inflation targeting monetary policy frameworks. The results of the empirical exercise using a panel dataset suggest that, over the last two decades, the volatility of inflation was similar among countries, even when controlling for monetary policy activity and other factors. In particular, there is only a weak and statistically not significant correlation between inflation volatility and country size. Also, point-targeting central banks (in contrast with range-targeters) and commodity exporters are only weakly associated with higher inflation swings. Equivalent conclusions are reached when decomposing inflation volatility in a transitory and a permanent component. I thus argue that small and large advanced open economies are exposed to global fluctuations to a comparable extent. A range of robustness tests confirm that the results are not sensitive to methodological choices and the relationship was not altered by the Great Recession or the low interest rate environment.

JEL classification: E31, E42, E50, F10, F41.

Keywords: Prices, Volatility, Globalisation, Inflation targeting.

Non-technical summary

The understanding of price dynamics is crucial for academics and policymakers alike. With globalisation phenomena and the rise of international integration, the assessment of inflationary pressures has evolved and the international environment gained prominence.

Many macroeconomic models for advanced economies proposed in the academic literature and also used by policy making institutions are laid out as small open economies. While this might be a sensible assumption for countries like New Zealand or Norway, it is less reasonable for larger ones such as the US or the euro area. Instead, it is more plausible that domestic developments or policy decisions taken in large open economies do spillover across borders and influence the external environment. Overall, it is a priori unclear whether small open economies are price takers and their exposure to global fluctuations is transmitted to volatile domestic prices. This is an empirical issue of high importance for price stability and the conduct of monetary policy.

The vast majority Central Banks with price stability mandates among industrialised nations adopts inflation targeting. Yet there exists a fair deal of nuances in their monetary policy frameworks. Some, for instance, have a point target while others express explicit ranges or confidence bands. This paper contributes to the debate on inflation targeting designs and it addresses two main questions. First, whether, among inflation targeting advanced economies, small countries experience higher inflation volatility. Second, whether inflation volatility is affected by having a point or a range inflation target.

In order to answer the questions posed, I analyse a panel of eleven advanced economies over the last two decades with inflation targeting central banks. The paper offers results from a cross-sectional and a time series analysis, as the drivers of inflation volatility may not be necessarily the same as the determinants of variations between countries. For the measurement of inflation volatility, I employ a range of statistical tools, from a simple standard deviation to an unobserved component stochastic volatility model.

Overall, I find that inflation volatility across advanced countries is comparable. Over the 1999-2018 period, the standard deviation of headline inflation is similar amongst advanced economies. This holds also when controlling for monetary policy activity, which can limit the pass-through of exogenous shocks to inflation. Point-targeting central banks (in contrast with range-targeters) and commodity exporters are only weakly associated with higher inflation volatility.

The findings of the study have several implications. First, the evidence suggests that the economic dimension is unrelated to inflation volatility, i.e. the degree of exposure of large and small open economies to global fluctuations is comparable. Second, they provide support to the seemingly strong *small* open economy assumption in popular macro models. Even large open economies display price-taking behaviours whereby they are influenced by the external environment. These results can also inform central banking and inflation targeting design discussions by shedding light upon drivers of price dynamics in an international context.

1 Introduction

The understanding of price dynamics has been central in the economic literature for many decades. Central banks have also devoted vast resources in the analysis and prediction of inflation behaviours. With globalisation phenomena and the proliferation of the international economics literature, the assessment of inflationary pressures has evolved: the international environment gained prominence in supporting domestic factors such as the output gap and wages. As developments in the rest of the world are becoming increasingly important on the domestic economy, policy makers and researches are devoting resources to study implications closely. In a fast-paced world, new technologies promoted long and complex supply chains bringing emerging markets to the centre of the stage. Pricing competition now has an international dimension and global super-star firms, with high bargaining power over workers, are arising. As a consequence, price dynamics are evolving and international factors become more prominent. The impact of the exposure to the global environment of small and large open economies on price fluctuations is thus a relevant question. Yet, the literature has so far devoted little attention to the effects of country size on domestic inflation volatility.

Many macroeconomic models for advanced economies proposed in the academic literature (e.g. Gali and Monacelli (2005); Adolfson et al. (2007)) and extensively used by policy making institutions (e.g. Brayton et al. (1996); Fenton et al. (2006); Christoffel et al. (2008); Burgess et al. (2013)) are laid out as small open economies.[1] This kind of framework implies that countries trade in international goods and capital markets, but are too small to influence world variables such as prices and interest rates. While this might be a sensible assumption for countries like New Zealand or Norway, it is less reasonable for larger ones such as the US or the euro area. Instead, it is more plausible that domestic developments or policy decisions taken in large open economies do spillover across borders and influence the external environment. This channel, not considered in such models, can also generate second round, sometimes referred to as spillbacks, or general equilibrium effects.

In addition, some countries, due to the nature of the most important sectors of their economies and propensity to trade, are intrinsically more exposed to global shocks. This is particularly relevant for commodity exporters, since the sale price of such goods is determined in global markets. As commodity prices weigh on the value of their output, it may pass through

[1]Examples of macro models employed in central banks modelled as small open economies include: BoE COMPASS model Burgess et al. (2013), ECB NAWM model Christoffel et al. (2008), BoC ToTEM model Fenton et al. (2006) and US Fed FRB/US Brayton et al. (1996)

to domestic inflation.

Equally, many of the empirical regularities on inflation found in the international macroeconomics literature span a large cross section of countries, the majority of which classify as emerging markets.[2] Yet, developed economies seem to behave somewhat differently compared to the 'average country' of the world.[3] Results do not appear to be robust to the subset of the data encompassing the richer end of the distribution of economies. Caution in extrapolating the results and policy implications of that strand of the literature to all countries is warranted.

As such, it is a priori unclear whether small open economies are price takers and their exposure to global fluctuations is transmitted to volatile domestic prices. This is an empirical issue of key importance for price stability and it is investigated in this paper.

Furthermore, the vast majority of Central Banks with price stability mandates among industrialised nations has followed the inflation targeting (henceforth, IT) trend which begun in the 1990s with the Reserve Bank of New Zealand. Yet, their monetary policy frameworks can have rather different set-ups. Some, for instance, have a point target (e.g. the US Fed and the Bank of Japan) while others express explicit ranges or tolerance bands (e.g. the Reserve Bank of Australia and the Bank of Canada).[4] On the one hand, a range target can give flexibility to the monetary policy and allows it to focus on other factors such as output, employment or financial stability. This is of particular relevance for Central Banks with multiple mandates, such as the US Fed, which is assigned with the dual mandate of price stability and maximum employment. On the other hand, tolerance bands or intervals can create uncertainty, harm the credibility and possibly lead to a dis-anchoring of inflation expectations. Furthermore, the Federal Reserve and the European Central Bank have recently announced a review of the broad monetary policy strategies and framework employed in the pursuit of their mandates. The analysis also aims to inform such discussions, from an international perspective.

This paper addresses two main questions. First, whether, among inflation targeting advanced economies, small countries experience higher inflation volatility. Second, whether inflation volatility is affected by having a point or a range inflation target. The countries included in the comparison are the euro area and key advanced economies whose macroeconomic developments are extensively monitored and analysed by market participants, academics and policy makers. The empirical answers to the questions posed fill a gap in the literature and provide

[2] See, for instance, Romer (1993); Lane (1997).

[3] Another example is Bowdler and Malik (2017).

[4] See Bernanke (2003) and citations therein for a review on inflation targeting, Wadsworth (2017) for an in depth comparison of international inflation targeting frameworks and Apel and Claussen (2017) for a discussion on the formulation of inflation targets.

contributions in various work-streams. First, I study whether the exposure of small and large advanced open economies to global fluctuations is comparable from a domestic prices dynamics perspective. To the extent of my knowledge, the relationship between country size, monetary policy framework and inflation volatility has, in fact, not be thoroughly analysed so far. Second, the investigation on point and range targeting central banks adds to the debate on inflation targeting designs. Third, I also contribute by improving the analysis compared to previous studies on inflation volatility by narrowing down the geographic set to a homogeneous cluster of highly developed countries. These have, in fact, been shown to behave differently compared to the global average. Fourth, by means of an unobserved component stochastic volatility model, I perform a permanent-transitory decomposition of inflation volatility to study the interactions of these components with economic size.

In summary, estimates indicate that the volatility of domestic prices in inflation targeting advanced economies over the last 20 years was comparable across countries and uncorrelated to their economic dimension. Point-targeting central banks (in contrast with range-targeters) and commodity exporters are only weakly associated with higher inflation volatility. Results 'validate' popular macroeconomics models set out as small open economies while informing policy makers and scholars in the field.

The rest of the paper is organised as follows. Section 2 reviews the various strands of the literature linked to this paper. Section 3 describes the panel dataset and the variables used in the investigation. The methodological framework and the regressions are laid out in Section 4. Section 5 provides the results of the empirical analysis and a battery of robustness tests while Section 6 concludes.

2 Related literature

In the international economics literature, inflation dynamics have been the subject of a variety of papers. The vast majority of academic investigations employ emerging markets data and focus on international and bilateral factors, such as propensity to trade, and different monetary policy frameworks (e.g. exchange rate targeting) that may affect price fluctuations. Romer (1993) and Lane (1997) are two prominent examples of studies on the influence of openness on average inflation. The former proposes a theoretical framework where more open economies gain less from inflation surprises because they would suffer more the adverse impact on output due to deterioration in terms of trade. Thus, the lower incentives on inflating of open economies, via unanticipated monetary policy loosening, predicts a negative relationship between inflation rates and degree of openness. Lane (1997), successively argues that this holds true even in small economies, which are unable to influence international prices. In the data, Romer (1993) finds a strong negative link between the two but the relationship breaks down among the most developed countries. On the other hand, Lane (1997), shows evidence of country size strengthening the link when included as control variable over the 1973 - 1988 sample period. This provides further motivation for the investigation carried out in this paper between the second moment of inflation, i.e. its volatility, and size.

In terms of monetary policy design, Agénor and da Silva (2019) provide a thorough review of the evidence on inflation targeting in the developing world and suggest that inflation targeting (IT) helped policy makers in meeting their inflation targets and reducing its variability. The trade-offs between different monetary policy regimes in dealing with terms of trade shocks are, for instance, investigated in Hove et al. (2016), who employ a panel VAR methodology among emerging markets. Comparing the robustness of IT to exchange rate targeting (ET) regimes, the authors find that IT is better equipped at controlling inflation and output gap in response to commodity shocks. ET, instead, is better at curbing FX volatility suggesting that exchange rate flexibility can insulate from the international environment.

The econometric machinery to model inflation has been developing steadily over the last three decades, in particular to accompany the analysis of monetary policy shock transmission. In more recent times, the focus is shifting from modelling only the first moment - mean - to also modelling its variance - (see Primiceri (2005); Koop et al. (2009); Eisenstat and Strachan (2016)). The argument is that the variance of inflation does not seem to be constant over time. Time varying parameters and stochastic volatility in Bayesian settings have since become prominent ways to allow for heteroskedasticity.

Outside the econometric modelling framework, the factors behind inflation volatility have, however, been studied by a small number of papers in the literature, with most investigating whether the drivers of the first inflation moment can also influence its second moment. For example, economic theory states that inflation volatility is affected by trade openness via two main channels: the reaction function of policy makers and the economic structure and consumption. However, the direction of the overall effect is ambiguous. Bowdler and Malik (2017), use a large panel dataset to investigate such a relationship and based on empirical estimates, they conclude that on average higher trade openness reduces volatility, but the relationship does not hold statistically among advanced economies. This shows once more, especially regarding the inverse relation between openness and inflation (volatility), the degree of heterogeneity across world economies where rich economies display different behaviours and therefore justify a particular attention be devoted. Conclusions on inflation levels are further corroborated by the findings in Andrews et al. (2009). Evidence from a panel dataset of 71 countries indicates that terms of trade volatility does influence inflation and output volatility but the magnitude depends on the monetary policy regime. Crucially, they argue that in small economies policy makers cannot dominate global factors and changes in relative prices but can affect how they impact the domestic economy.

In addition to the connection with the literature on new open-economy macroeconomics, this paper also resonates with the more recent and growing body of research on the impact of globalisation on the inflation process.[5] The long standing globalisation trends have increased trade and financial flows among countries where global value chains connect integrated markets. Prominent examples include Borio and Filardo (2007) and Forbes (2019) and they call for a shift from a *'domestic-centric'* to a more *'global-centric'* framework to analyse inflation. The empirical evidence which supports the inclusion of global factors in models of domestic inflation also provides a further motivation to this paper. Phillips-curve specifications and, more generally, inflation equations should be augmented by global factors in order to no longer neglect the external environment. The sensitivity of different economies to such factors and its implications on cross-sectional differences such as inflation volatility is, however, unclear.

Lastly, I also speak to the enduring and multifaceted debate on the international dimensions of optimal monetary policy. For example, Corsetti and Pesenti (2005) find an important role for second moments as they argue that some 'inward-looking' policy objectives are myopic since the exchange rate swings, reflected in volatile profits, are compensated by firms by setting higher prices. Strictly related to this, are the discussions on the specification of central bank targets. Castelnuovo et al. (2003), for instance, argue that a range target can easily accommodate moderate inflation swings and help central banks convey the message of the 'imperfect controllability' of price developments to the public. Point targets, instead, can provide better guidance for the anchoring of inflation expectations. Bernanke et al. (2001), however, warns that failure to maintain inflation within a range target might be perceived by agents as a more serious policy deficiency than failure to hit a point one, as the latter inevitably happens regularly.

[5] See Lane (2001) for a survey.

3 Data

The analysis conducted in the paper focuses on 11 advanced OECD member economies. European countries not part of the EMU are studied individually whereas euro area members are treated as a group as they share a common monetary policy. Namely, in descending order of 2018 GDP in USD, the economies included in the sample are the United States (US), the euro area (EA), Japan (JP), the United Kingdom (UK), Canada (CA), South Korea (KR), Australia (AU), Switzerland (CH), Sweden (SE), Norway (NO) and New Zealand (NZ). The sample starts in 1999Q1, when the Euro was introduced, and ends in 2018Q4. The frequency of the data is quarterly, constrained by the availability of GDP figures across all regions and CPI numbers in Australia and New Zealand. To maximise comparability and conceptual homogeneity across regions throughout the study, CPI indexes are used for all countries, with the exception of the euro area, where HICP is used.[6]

The homogeneity in a variety of economic aspects of the regions selected helps to narrow down the 'moving parts' and improve the empirical estimation of the relationship studied by focusing on the variables of interest. On the one hand, the countries analysed have modern inflation targeting central banks - with aims around 2% - have not experienced major outbreaks of inflation over the sample period and are active participants in global trade. On the other hand, they crucially differ in their size and inflation targeting framework, the key points of interest of this study.

Table 1 presents stylised facts including an overview of the inflation targeting/objective frameworks in place in the countries considered. Out of the thirteen countries analysed, five specify an explicit target range, or a tolerance band, around a point target (GB, AU, CA, NZ, CH) while the other six only have a point target. I refer to these countries as range targeters and point targeters, respectively.[7]

Columns 7 and 8 contain summary figures about the first two moments of year-on-year CPI/HICP headline inflation of the economies considered. The average inflation rate over the sample period (1999-2018) was 1.72 with Japan recording the lowest value and Australia the

[6] The HICP is an harmonised index of consumer prices published by Eurostat which is specifically designed to address cross-country heterogeneity within the economic and monetary union.

[7] The euro area is classified as a point targeter as suggested by President Draghi in the press conference on 25 July and 12 September 2019.
Although the US Fed declared an explicit inflation target in 2012, its former Chairman Bernanke has often argued they have gradually moved to an implicit inflation targeting system under Volker and Greenspan - see Bernanke (2003) and citations therein.
Given the idiosyncrasies of the monetary policy framework of the Bank of Japan, I check that the main results hold also when dropping Japan from the sample.

highest one, while the standard deviation of inflation was 1.04 with Canada and New Zealand at the extremes. The picture painted by core inflation numbers is very similar. Figure 1 displays the standard deviation of headline and core CPI/HICP inflation. As one could expect, the volatility of core inflation of each country is lower compared to its headline volatility. The similarities in the distribution of inflation rates across the economies analysed confirm that none of the regions has experienced extreme events of high inflation or deflation. In fact, average inflation rates have been in general within the target range or less than 2 percentage points away from the point target. These inflation targeting central banks have, thus, been able to deliver on their price stability mandates and it further suggests broad similarities in the underlying economic structure and comparability among the regions.

Finally, Table 1 also splits the countries between range and point targeters and highlights commodity exporters. The latter might experience higher inflation volatility driven by their intrinsically larger exposure to price swings in global commodity markets. The definition of commodity exporters relies upon the dependence of a country on primary goods exports, including oil, gas, coal, metals and food. Countries are classified as commodity exporters if i) total nominal exports are composed of primary goods for 20% or more and ii) net primary exports are more than 5% of the average of nominal imports and exports. Australia, Canada, Norway and New Zealand comfortably fall within this definition while the rest have a considerable margin. In particular, the classification designates Canada and Norway as energy exporters, Australia as metals exporter and New Zealand as food exporter. This aims at improving on the IMF World Commodity Exporters database (WCED) which uses a similar definition but does not include food as a primary product. Andrews et al. (2009), like the IMF, define commodity producers and achieve a similar classification as ours, with New Zealand being the only difference.

Figure 2 depicts the average volatilities within these groups. The mean standard deviation of point targeters is marginally higher compared to range targeters (1.08 versus 0.99). Commodity exporters have an average volatility of 1.07, which is 0.04 percentage points above the rest of the countries. The striking similarity would suggest that whether a country is a point or range targeter or a commodity exporter does not seem to be a relevant factor in explaining inflation fluctuations. Results of formal statistical tests on the hypotheses I put forward are included in the next section.

One important caveat is that while external shocks do influence the domestic prices of small open economies more, the respective central banks may also adjust policy rates to address these global developments, thereby muting the impact on inflation volatility. The endogenous response of policy makers may be a confounding factor, masking the true results. I therefore propose a proxy for monetary policy activity by calculating the number of changes in the policy rates over time, which will be used in the subsequent analysis as a control variable.

Finally, I also include other variables identified by the literature investigating the determinants of the first and second moment of inflation. In particular, I calculate a measure of openness as the GDP share of imports and exports, in line with Bowdler and Malik (2017).[8] Mathematically,

$$OPEN_{i,t} = \frac{IM_{i,t} + EX_{i,t}}{GDP_{i,t}} \tag{1}$$

The second measure I employ, in the spirit of e.g. Andrews et al. (2009), is the volatility of imports terms of trade. The variable is computed as the standard deviation of the year-on-year percentage change of the ratio of the export price index to the import price index. This matches the transformation applied to the CPI indices to obtain inflation volatility.

3.1 Preliminary evidence

I start answering the research question by investigating whether large countries have experienced a lower inflation volatility by means of a simple t-test. Rather than setting an arbitrary threshold to define small and large economies, I rank countries by size and define the bottom three (NZ, NO, SE) as small and the top three (JP, EA, US) as large economies. The average real GDP in 2018 (at 2010 prices and exchange rates) stood at 422 bn US dollars for the first group and 12,715 bn US dollars for the second, roughly 30 times higher. Table 2 reports the average inflation volatility for the two sets of countries for a variety of measures and the p-value of their difference.[9] All p-values are above conventional confidence levels, thereby not rejecting the null hypothesis of an equivalence of the two means. This holds for the full sample studied, 1999-2018, and a reduced sample that excludes the 2008-2014 period characterised by the Great Recession and the European sovereign debt crisis. Notwithstanding the simplicity of the test with a limited sample size and no controls, I classify this as preliminary evidence indicating that, over the sample considered, advanced open economies have experienced comparable levels of inflation volatility.

[8] For the euro area I only consider extra EA trade and exclude trading between euro area countries to avoid an upward bias.

[9] see the Robustness section for a walk-trough of the different measures

4 Methodology

The analysis rests on the assumption that inflation is locally stationary and therefore its variance is theoretically measurable and not infinite. This means that while in the long run inflation can be regarded as a non-stationary process, whose variance would not be bounded, a standard deviation in smaller sub samples can be estimated. Hendry (2001) for instance, argues in favour of treating inflation as an I(0) process. More recently, Eisenstat and Strachan (2016) discuss the trade-offs between modelling volatility as a stationary or random walk process in a time varying parameter setup. On the one hand, theory would suggest stationary formulations to address unboundedness concerns. On the other hand, however, a nonstationary process allows a more accurate description of the large and slow-moving swings recorded in volatility over the last decades. Empirically they find that *"estimates of volatility differ little among the specifications and the estimated parameter values from the stationary model are close to the nonstationary region"*.

In order to assess whether large and small open economies experience the same inflation volatility I tackle the question from different angles. The drivers of the dynamic evolution of inflation volatility over time may, in fact, not be necessarily the same as the determinants of cross-sectional differences. By undertaking a cross-sectional and a time series analysis the paper offers two different points of view. This also allows to exploit the different dimensions of the constructed panel dataset.

An additional issue is related to the measurement of inflation volatility, which can be considered as unobservable. To address possible concerns, I employ a range of statistical tools, from a simple standard deviation to an unobserved component stochastic volatility model, to quantify and measure the latent variable as precisely as possible. Details on the volatility estimates are provided below.

4.1 The cross-sectional and panel dimensions

I start by estimating the volatility on the entire sample period and analyse cross-sectional variations among regions. On the one hand, this procedure allows to use a large number of observations to better estimate the standard deviation of inflation. On the other hand, this collapses the time series, leaving only one dimension and fewer observations left. In the second leg of the analysis, I estimate the inflation volatility over different periods by computing the standard deviation on rolling windows of 2, 4 and 6 years. While this reduces the number of data points used to measure the volatility, it preserves the time dimension and allows running panel regressions. To minimise the persistence mechanically generated by the rolling estimates I also use non-overlapping windows of the same lengths.

Furthermore, measuring inflation volatility over the entire sample period allows a better cross-sectional comparison abstracting from time fluctuations while dynamic measures can shed light on cyclical behaviours of inflation. Thus, the two parts of the analysis can tackle the problem from different angles and provide complementary results. The estimated regressions are explained in more details in the next Section.

4.2 The unobserved component stochastic volatility model

Typical macroeconometric regressions rely on the homoskedasticity assumption and, by nature, cannot deal with a non-constant error variance. In the inflation modelling literature there has been and increasing interest in frameworks that allow for hetesokedasticity. The most common setup in macroeconomics is a non-linear state space which specifies a random walk evolution for log volatility as the state equation.[10] The framework is an alternative to (G)ARCH models, where the variance is assumed to be a deterministic and observable process.[11]

ARCH models are stationary autoregressive models for the log volatility commonly employed in the finance literature as they provide a good approximation of many financial processes that exhibit volatility clusters and a quickly mean-reverting variance. Macroeconomic time series, however, often display slower movements that are not well described by stationary processes. Inflation volatility, albeit unobservable, has commonly been estimated to have large low frequency movements that are better captured by stochastic volatility frameworks (see, for example, Eisenstat and Strachan (2016)).

Although a random walk process has the disadvantage of being unbounded in probability because of its non-stationarity, it is arguably a close description of the true process. Such models have proven useful for structural interpretations (Primiceri (2005)) as well as for forecasting (Stock and Watson (2007)).

I draw from this literature and estimate inflation volatility via a parsimonious unobserved component stochastic volatility (UC-SV) model for each country considered (the subscript i in

[10] See Eisenstat and Strachan (2016) for a discussion on modelling volatility as a stationary or random walk process in a time varying parameter setup.

[11] See Shephard (1996) for a comparison between ARCH and stochastic volatility models.

the equations below is omitted to simplify the notation).

$$\pi_t = \tau_t + e^{(v_t/2)}\varepsilon_t^{\pi}, \tag{2}$$

$$\tau_t = \tau_{t-1} + \omega_\tau \varepsilon_t^{\tau}, \tag{3}$$

$$v_t = v_{t-1} + \omega_v \varepsilon_t^{v} \tag{4}$$

where π_t is the inflation rate and τ_t is the unobserved inflation trend, $\varepsilon_t = (\varepsilon_t^{\pi}, \varepsilon_t^{\tau}, \varepsilon_t^{v})$ is i.i.d. $N(0, I_3)$ and the model parameters are ω_τ and ω_v.[12] I use the estimated time varying volatility v_t for each country to assess similarities across regions. The model is considered as a more sophisticated measurement device for volatility compared to a simple computation of a standard deviation. As I do not expect v_t to diverge substantially from simpler volatility estimates using rolling windows it can be used as a robustness check to further corroborate the main results. The estimation is carried out via Bayesian techniques using the auxiliary mixture sampler proposed by Kim et al. (1998). Posterior estimates are based on 100,000 draws after having discarded the first 10,000.

I go a step further and decompose inflation into a trend and an inflation gap component, where each component is characterised by an independent stochastic volatility process. To this end, I change model (2)-(4) to match the Stock and Watson (2007) specification. The UC-SV model I estimate can be written in state space form as:

$$\pi_t = \tau_t + exp(h_t/2)\varepsilon_t^{\pi}, \tag{5}$$

$$\tau_t = \tau_{t-1} + exp(g_t/2)\varepsilon_t^{\tau}, \tag{6}$$

$$h_t = h_{t-1} + \omega_h \varepsilon_t^{h}, \tag{7}$$

$$g_t = g_{t-1} + \omega_g \varepsilon_t^{g} \tag{8}$$

where π_t is the inflation rate and τ_t is the unobserved inflation trend. The stochastic volatilities, h_t and g_t, again, evolve as independent random walks and $\varepsilon_t = (\varepsilon_t^{\pi}, \varepsilon_t^{\tau}, \varepsilon_t^{h}, \varepsilon_t^{g})$ is i.i.d. $N(0, I_4)$. Unlike Stock and Watson (2007), who fix the parameters of the stochastic volatility $\omega_h^2 = \omega_g^2 = .2$, I treat them as independent coefficients and estimate them. Since these parameters control the smoothness of the volatility estimate, I want to avoid imposing a number for all geographies

[12] I assume a normal prior for $\omega_\tau \sim N(0, \sigma^2_{\omega\tau})$. In the spirit of Stock and Watson (2007), the prior for ω_v is assumed to $\sim N(0, .2)$ which implies centring the prior for ω_v^2 around 0.2.

but let the model choose more appropriate values based on the data.[13]

5 Empirical Evidence

5.1 The cross section

To formally test the correlation between these variables and the standard deviation of headline inflation (denoted π), I consider the following regression:

$$\hat{\sigma}_i^{\pi} = \alpha + \beta_1 GDP_i + \beta_2 RANGE_i + \beta_3 MPA_i + \beta_4 COMM_i + \varepsilon_i \quad (9)$$

where $\hat{\sigma}_i^{\pi}$ is the standard deviation of inflation for country i, α is a constant, GDP_i is the 2018 GDP in US dollars[14] of country i, $RANGE_i$ is a dummy variable that takes the value of 1 if the country is a range targeter or 0 if it is a point targeter, MPA_i is the monetary policy activity measure and $COMM_i$ is the commodity exporter dummy that takes the value of 1 for the four countries indicated in Table 1 and zero otherwise and ε_i is the error term. Estimates of the coefficients β_1 and β_2 in Eq (9) are the focus of this study and are reported in Table 3. The hypothesis is that $\beta_1 \neq 0$ and $\beta_2 \neq 0$ indicating that country size and the monetary policy regime can influence the degree of inflation fluctuations. Due to the limited number of observations in the cross section, I pay particular attention to the saturation of this regression and propose a parsimonious specification. I rely on economic theory for the choice of the independent variables included in the baseline.

Cross sectional estimates are reported in Table 3. The large standard errors in parentheses suggest no significant correlation between headline inflation standard deviation over the sample period and GDP, monetary policy activity, range targeter and commodity exporter dummies (column 1). I regress each of these variables individually in columns 2-5 but the conclusion remains unaltered.

I thus argue that, in the cross section, the size of the country does not influence headline inflation volatility. Similarly, I find no evidence of a relationship between inflation swings and having a point or a range inflation target. These results are further corroborated by Figures 3 and 4 where I plot scatters of inflation volatility against GDP and monetary policy activity. No clear relationship can be observed. The US, the largest country by GDP, has the second highest volatility while Japan and the euro area (the second and third economies by size) have

[13] I assume a normal prior $\omega_j \sim N(0, \sigma^2_{\omega j})$ for $j = h, g$. $\sigma^2_{\omega j} = 0.2$ so that $E\omega_j^2 = 0.2$ which implies centring the prior for ω_j^2 around 0.2.

[14] If the average GDP over the sample is used instead, results do not change qualitatively.

experienced inflation swings only larger than Switzerland, the UK and Canada. In terms of monetary policy activeness countries are closely clustered around 33 interest rate changes with the sole exception of Japan.[15]

In the spirit of the related literature, I also test whether the degree of openness or the volatility of imports terms of trade can affect inflation fluctuations (columns 6-9). Openness in line with Bowdler and Malik (2017) has a negative impact on inflation volatility but I also find that it lacks statistical significance in the sample. The parameter estimate of terms of trade (ToT) volatility is also not significant. Overall, the difference between the results of previous papers and mine indicates that inflation volatility in advanced economies with inflation targeting central banks is not driven by the same factors affecting price movements in developing countries. As the cross section estimates could be subject to a small sample bias, I now turn to panel and stochastic volatility estimates.

5.2 The panel

For the second type of analysis I estimate fixed effect panel regressions, for both rolling and non-overlapping windows of different lengths. Albeit creating fewer observations in the time dimension, non-overlapping windows can address concerns over the persistence in the variables generated by the rolling windows. Indeed, a drawback of employing rolling estimates is that due to their overlapping nature, they create a highly persistent variable and induce autocorrelation to the residuals of the regressions. In order to mitigate such concerns I swap rolling windows for non-overlapping ones, in order to ensure that each inflation observation is only used once for the estimation of its volatility. The panel regressions take the following form:

$$\hat{\sigma}(l)^{\pi}_{i,t} = \beta_1 GDP(l)_{i,t} + \beta_2 MPA(l)_{i,t} + \beta_n X(l)_{n,i,t} + \eta_i + \varepsilon_{i,t} \tag{10}$$

where $\hat{\sigma}(l)^{\pi}_{i,t}$ is the inflation volatility for region i, at time t estimated on a (rolling) window of l years. Likewise, $GDP(l)_{i,t}$ and $MPA(l)_{i,t}$ are the GDP and monetary policy activity measures for region i, at time t estimated on a (rolling) window of l years. $\varepsilon_{i,t}$ is the error term and β_n is the coefficient of the control variable $\beta_n X(l)_{n,i,t}$. When I include the range and/or commodity exported dummy, the country fixed effect η_i have to be removed due to collinearity. The main tested hypothesis is whether the size of a country has an influence on the volatility of headline inflation, i.e. $\beta_1 \neq 0$ in Eq (11). Similarly, but without claiming a

[15] I test and verify that this result is robust to the exclusion of Japan.

causal direction, I hypothesise that monetary policy activity is correlated with the standard deviation of inflation, or in other words that $\beta_2 \neq 0$.

Tables 4-5 present the results of the panel estimates for rolling and non-overlapping windows, respectively. Since the choice of the window length l is somewhat arbitrary, I run a similar set or regressions for three values of l, namely 2, 4 and 6 years. In all cases, however, I do not detect a significant relationship between inflation volatility and GDP.

Starting with the rolling window measure, I first note that the results are not driven by the length of the rolling window but are qualitatively comparable across specifications. I thus focus on the four-year window, shown in columns 3-4 of Table 4. In column 3, the country fixed effects estimates support the cross sectional results: the coefficients of country size, monetary policy activity terms of trade volatility and openness are not statistically significant. In column 4, I remove the country fixed effect to insert the range targeter and commodity exporter dummies. While the statistical insignificance of GDP persists, the standard errors of other regressors, e.g. monetary policy activity, terms of trade volatility and openness, markedly decrease, pointing toward a statistical significance between 1 and 10%. The estimates indicate that range targeters experience lower inflation swings while commodity exporters face slightly higher volatility, in line with theoretical predictions. However, the decrease in the t-statistics once the fixed effects are added could be interpreted as evidence of a strong presence of country specific factors driving inflation volatility that are not common across the sample. Lastly, in the even columns I note that the significance of the monetary policy activity variable diminishes as the window lengths increases. This is in line with theoretical predictions on long-run neutrality of central banks' actions.

Non-overlapping window estimates are reported in Table 5 for the three different window lengths. Under all specifications the GDP coefficient is not statistically different from zero. In addition, it flips sign when moving from 2- and 6-year windows to 4 years. This constitutes further indication of a non-existing (or very weak) relationship between size and inflation swings. The significance of the coefficients of the Range and Commodity dummies are low but the signs and magnitude are broadly comparable to the overlapping windows estimates.

Given that one of the reasons for producing non-overlapping windows estimates is to address a possible autocorrelation of the error term in the rolling window specification, I formally test for serial correlation of the residuals of the regressions reported in Table 5 following Wooldridge (2002) as standard tests cannot be applied to panel estimates. The method checks the error term of the first differenced regressions, which in this case, collapsing all explanatory variables in X, is equal to:

$$\Delta\hat{\sigma}(l)^{\pi}_{i,t} = \Delta\beta X(l)_{i,t} + \Delta\varepsilon_{i,t} \tag{11}$$

where $\Delta\varepsilon_{i,t} = \varepsilon_{i,t} - \varepsilon_{i,t-1}$. If residuals are not autocorrelated, then $corr(\Delta\varepsilon_{i,t}, \Delta\varepsilon_{i,t-1}) = -0.5$. This can be easily checked regressing by the residuals on their lags and testing whether the estimated parameter is equal to -0.5 under the null hypothesis. Table 6 shows the estimates of the serial correlation in the residuals, which are all fairly close to the null. The p-values of the F-test indicate that, at the 90% confidence level, there is no evidence of autocorrelation for any window length.

5.3 Estimating and decomposing stochastic inflation volatility

The estimated inflation volatilities using UC-SV models for all the regions considered are plotted in Figure 5. The chart depicts the time-varying volatility of Eq. (2) and Figure 6 captures the permanent-transitory decomposition of the model in Eq. (5)-(8). Starting with the first chart, a few observations are worth emphasising. First, geographies appear to move largely in tandem especially after the financial crisis where the cross-country dispersion is minimised. Around the crisis itself, I register a tendency common to all countries to experience heightened inflation volatility. Second, no single region emerges as an outlier for the whole period, although there are important spikes in the first half of the sample. The most prominent are the peaks in US volatility around 2009, Australia in 2001 and Norway in 2004.

Turning to Figure 6, the decomposition of inflation between a trend and a transitory component also reveals similarities across the economies studied. Over the sample period 1999-2018, the model attributes the vast majority of inflation volatility to the transitory component while the permanent one is remarkably stable. Furthermore, given that for both models I estimate the ω_i coefficients rather than calibrating them, I can also speak to the smoothness of the volatility time series. I find that the time-varying standard deviations are characterised by low frequency movements and there is a large degree of homogeneity across economies. All of the above evidence is in line with Stock and Watson (2007) estimates for the US. They conclude that between 1953 and 2004, the standard deviation of the permanent component is subject to the most substantial movements, moderating in the 1990s until the end of the sample. The variance of the transitory innovation, in contrast, shows minor fluctuations until around 2000, when it edges up substantially. Chan (2018) also reaches similar conclusions for G7 countries from 1955 through 2013.

Volatility estimates produced by the UC-SV models are then plugged in fixed effect panel regressions. The empirical choices of such analysis, such as the regressors used, aim to speak directly at the findings presented above and captured in Tables 3-5 and therefore offer good grounds for comparison. Panel regression results are reported in Table 7. The dependent variable in Column 1 is v_t, the stochastic volatility time series generated by Eq. (2)-(4). The sign of the GDP coefficient is negative, yet its standard error is too large for the effect of this variable to be deemed statistically significant, further corroborating previous findings of the paper. The monetary policy activity estimate instead, is positive and significant suggesting the existence of a strong relationship between central banks actions and inflation swings. Terms of trade and openness do not appear to be correlated with overall inflation volatility. The regressions presented in columns 2-3 use h_t, g_t as left-hand side variables, i.e. the variances of the trend and transitory components, respectively. Estimates in Column 3 are qualitatively equivalent to the ones in Column 1, where monetary policy activity is the only significant variable. First, numerically this is to be expected since, as the decomposition as shown, the dynamics of v_t are largely driven by the transitory part. Second, economic theory would also suggest that monetary policy only has temporary and not permanent effects. On the other hand, the terms of trade and the degree of openness of a country can act as more structural drivers of long run economic dynamics. Indeed, the regression results reported in Column 2 support this hypothesis, where the trend component is significantly correlated with ToT and openness but not influenced by the monetary policy indicator. Like Bowdler and Malik (2017), I also provide evidence that openness has a negative effect on (trend) inflation volatility.

Overall, the cross sectional and panel analysis speak in the same direction. The empirical evidence presented leads us to a set of conclusions. First, among developed economies with inflation targeting central banks, country size does not influence the inflation volatility experienced. Second, having a range targeting monetary policy framework is weakly associated with statistically lower levels of inflation volatility, while commodity exporters are weakly correlated with higher price swings. Third, the importance of country-specific factors supports the notion that domestic factors still play a relevant role. Fourth, country size does not seem to matter even when decomposing inflation volatility into transitory and permanent components.

5.4 Robustness

I devote this subsection to test the sensitivity of the main results to the various empirical choices made. Related Tables are included in the Appendix.

The first set of tests is about the measurement of headline inflation volatility. To this end I check whether using a seasonally adjusted CPI index or a log standard deviation makes a difference. For the latter, I follow Bowdler and Malik (2017) and recompute the volatility of inflation as:

$$\hat{\sigma}_i^{\pi} = ln\,(1 + std(\pi_i)) \tag{12}$$

A log transformation would comparatively decrease the relative importance of large values and increase that of small ones. This effect is attenuated if I add one to the estimated standard deviation.

Tables 8 and 9 replicate the cross sectional analysis using a different measurement methodology of the dependent variable. Coefficient estimates are qualitatively similar and show that the baseline result is not affected by a change in the computation technique of inflation volatility.

Second, I turn to other commonly used price indexes. In particular I consider core CPI and the GDP deflator. In comparison to headline CPI, core removes volatile items such as oil and food and is thus characterised by a more persistent behaviour. Central banks often rely on this index in order to disentangle temporary shocks from structural developments. The GDP deflator, instead, differs in two main directions. First, it measures changes in the prices of goods and services purchased by consumers, businesses, government and foreigners and not by consumers only. Secondly, it only includes goods and services produced domestically whereas CPI also covers imports.[16]

In the context of the analysis undertaken in this paper, these discrepancies have important implications. In particular, the exclusion of commodities, which are traded and priced in global markets, in core inflation can give a limited and biased view on the impact of global shocks on domestic prices. The GDP deflator, on the other hand, encompasses goods and services produced locally and bought by a larger range of economic actors, including trading partners. It is consequently a more suitable indicator to investigate the transmission of global prices on

[16] There are other differences in the weights of the items included in the indexes and the computation methodology. It is, however, unclear why these should be correlated with the transmission of global shocks to inflation volatility and are therefore not likely cause a bias. See, e.g. Church (2016) for further details.

the prices of domestically produced goods and services.

The cross sectional regression estimates of regressions with the GDP deflator as dependent variable are included in Table 10. On its own, country size, reported in column 2, appears to have a negative and statistically significant relationship with GDP deflator inflation volatility, albeit at 90% confidence level. The coefficient of the commodity exporter dummy (column 5) is also significant at the 5% level and positive. Its magnitude is economically important as it indicates that while the standard deviation of non-exporters is around 0.95, countries more involved in trading commodities have an average inflation volatility three times higher (computed as the constant of 0.945 plus the dummy coefficient of 1.999). Columns 7 and 8 report the coefficients of the standard deviation of the unemployment rate (URX) and terms of trade (ToT), which are both only significant at the 10% level. The negative sign of former would be in agreement with a theoretical second moment Phillips curve, where the volatilities of unemployment and inflation are inversely related. The positive relationship of terms of trade standard deviation is also in line with theory, which would suggest comovements of domestic inflation and ToT. In column 1, however, I include the multiple independent variables of the baseline regressions. GDP loses its statistical significance, while the commodity exporter dummy remains both statistically and economically very relevant.[17] I therefore argue that the results presented here provide evidence in favour of the absence of a relationship between economic size and inflation volatility. It can instead be driven by the extent of a country involvement in international commodity markets. Put differently, there may exist a relationship between size and whether an economy is a commodity exporter but it is the latter that affects inflation volatility and not the dimension of the region per se.

Third, since the investigation of the paper on the relationship between size and inflation fluctuations has so far assumed no changes over time, I estimate a set of regressions in order to analyse whether the findings are sensitive to the time period considered, with particular attention on the great recession and the European debt crisis. In the interest of brevity, I only present findings from the fixed effect estimator on 4-year rolling windows. I start in column 1 of Table 11, which presents coefficient estimates of the pre crises period (1999-2007). Next, I add a crises dummy, which takes the value of 1 between 2008 and 2014, to encompass the global financial crisis and the Euro crisis (column 2). Lastly, column 3 contains the results for the post crises period, namely 2015 to 2018. Even though some of the variables become significant under the range of samples analysed, the main result highlighted throughout the

[17]Given the small sample size, adding too many explanatory variables would saturate the regression.

paper persists. For instance, terms of trade volatility and openness have p-values below 0.1 post crises and 0.05 pre crises, respectively. This evidence on the time varying influence of factors is in line with the recent work on (the first moment of) inflation by Forbes (2019). While it is worth noting that country size and openness have affected inflation volatility differently during the crises (and this difference is statistically significant), the overall result remains. Pre, post and during crises periods the effect has no statistical relevance. Unreported estimates show that the overall coefficient (the sum of the relevant variable and its crises interaction term) is statistically not different from zero.

Fourth, to further test whether possible serial correlation in the residuals of the panel regressions is polluting the results, I re-estimate the variance-covariance matrix of the errors a la Newey and West (1987) to obtain a heteroskedasticity and autocorrelation consistent covariance matrix (HAC). I set the maximum lag order of the autocorrelation to control for equal to the length of the rolling windows in quarters. Results of panel regressions with HAC robust standard errors are reported in Table 12 and still show no significant impact of country size on inflation volatility.

6 Conclusions

In the study of inflation dynamics, globalisation and a high degree of financial and economic interconnectedness have brought to the fore external factors, to the detriment of domestic variables. At the same time, many macroeconomic models which have gained prominence in the literature and are also used by policy makers frame domestic countries as small open economies. The framework implies that small and large economies are price takers and, *ceteris paribus*, are equally exposed and affected by shocks in the external environment. In other words, country size is not associated with the degree of inflation fluctuations. In this paper I analyse a panel of eleven advanced economies over the last two decades with inflation targeting central banks to empirically investigate whether economic size influences inflation volatility.

Overall, I find that inflation volatility across advanced countries is comparable. Over the 1999-2018 period, the standard deviation of headline inflation is similar amongst advanced economies. This also holds when controlling for monetary policy activity, which can limit the pass-through of exogenous shocks to inflation. There are only feeble differences between point and range targeters and commodity exporters, pointing to smaller price swings for range targeters and non-commodity exporters. Contrasting these results with the previous literature on developing countries, I find that emerging markets and advanced economies behave differently and thus caution on large cross-sections is necessary. I argue that the terms of trade and openness play a minor role on total inflation volatility. Only when decomposing the latter into permanent and transitory components, do I see terms of trade and openness influencing the permanent part. The data only reveals weak evidence of commodity exporters facing larger inflation swings due to the more elevated exposure to global shocks to commodity prices. Sensitivity analysis tests on the computation of volatility, the inflation index chosen and the time period considered confirm the robustness of the results.

The findings of the study have several implications. First, the evidence suggests that the economic dimension is uncorrelated to inflation volatility, i.e. the degree of exposure of large and small open economies to global fluctuations is comparable. Second, they provide support to the seemingly strong small-open economy assumption in popular macro models. Even large open economies display price-taking behaviours whereby they are influenced by the external environment. Third, a stubbornly low inflation paired with an extended period of loose monetary policy triggered framework reviews in major economies such as the US and the euro area and other central banks are likely to follow. My results can also inform central banking and inflation targeting design discussions by shedding light upon drivers of price dynamics in an international context.

Tables

Table 1
Data overview

Country	Central Bank	First inflation target	Target point	Target range	Target index	Inflation avg	Inflation Std dev	Size	Commodity exporter
AU	Reserve Bank of Australia	1996		2-3	CPI	2.64	1.12	1554	Yes
CA	Bank of Canada	1991	2	1-3	CPI	1.92	0.84	1909	Yes
CH	Swiss National Bank	1999		0-2	CPI	0.51	0.88	675	
EA	European Central Bank	1998	<2		HICP	1.72	0.91	14036	
GB	Bank of England	1992	2	1-3	CPI	2.00	0.86	2883	
JP	Bank of Japan	2013	2		CPI	0.07	1.01	6194	
KR	Bank of Korea	1998	2		CPI	2.44	1.20	1565	
NO	Norges Bank	2001	2		CPI	2.11	1.06	490	Yes
NZ	Reserve Bank of New Zealand	1989	2	1-3	CPI	2.04	1.25	183	Yes
SE	Riksbank	1993	2		CPI	1.24	1.12	591	
US	US Federal Reserve	2012	2		PCE	2.19	1.20	17913	

Notes: Inflation is calculated as Y-o-Y percentage change of non seasonally adjusted CPI/HICP quarterly data (with quarterly values calculated as an average over the quarter, with the exception of AU and NZ, for which data is only available at quarterly frequency), over the period 1999Q1-2018Q4. Size of the country is measured by 2018 GDP at 2010 prices & exchange rates in bn USD.

Table 2
Inflation volatility t-test

	Smallest	Largest	p-value
	Full Sample		
Headline vol	1.142	1.041	0.378
Headline log vol	0.761	0.712	0.369
Core vol	0.722	0.575	0.261
GDP def vol	2.786	0.808	0.224
Headline season adj vol	1.137	1.068	0.535
	Excluding Crises		
Headline vol	1.036	0.814	0.160
Headline log vol	0.761	0.712	0.369
Core vol	0.713	0.481	0.134
GDP def vol	2.666	0.778	0.264
Headline SA vol	1.034	0.784	0.154

Table 3
Headline inflation - cross section

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2018 USD GDP	-1.285	0.918							
	(10.062)	(8.437)							
Range targeter	-0.138		-0.093						
	(0.094)		(0.094)						
MP activity	0.003			0.004					
	(0.002)			(0.003)					
Commodity exporter	0.072				0.041				
	(0.110)				(0.100)				
GDP_USD std						0.000			
						(0.000)			
URX std							0.033		
							(0.132)		
TOT std								0.019	
								(0.013)	
Openness									-0.128
									(0.126)
Constant	0.980***	1.037***	1.083***	0.912***	1.026***	1.022***	1.010***	0.956***	1.124***
	(0.094)	(0.061)	(0.047)	(0.103)	(0.057)	(0.059)	(0.128)	(0.087)	(0.095)
Observations	11	11	11	11	11	11	11	11	11

Heteroskedasticity robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4
Headline inflation - rolling windows

VARIABLES	(1) $\hat{\sigma}^{\pi}$ (2yr)	(2) $\hat{\sigma}^{\pi}$ (2yr)	(3) $\hat{\sigma}^{\pi}$ (4yr)	(4) $\hat{\sigma}^{\pi}$ (4yr)	(5) $\hat{\sigma}^{\pi}$ (6yr)	(6) $\hat{\sigma}^{\pi}$ (6yr)
GDP (2yr)	0.167	0.016				
	(0.166)	(0.018)				
MP activity (2yr)	0.168	0.209***				
	(0.189)	(0.053)				
TOT vol (2yr)	0.047	0.042***				
	(0.029)	(0.007)				
Openness (2yr)	-0.362	0.084				
	(0.457)	(0.074)				
GDP (4yr)			0.372	0.024		
			(0.289)	(0.017)		
MP activity (4yr)			0.135	0.140**		
			(0.255)	(0.056)		
TOT vol (4yr)			0.045	0.034***		
			(0.036)	(0.006)		
Openness (4yr)			0.272	0.170**		
			(0.473)	(0.070)		
GDP (6yr)					0.419	0.026
					(0.392)	(0.016)
MP activity (6yr)					0.041	0.047
					(0.247)	(0.060)
TOT vol (6yr)					0.045	0.025***
					(0.044)	(0.005)
Openness (6yr)					0.707*	0.194***
					(0.389)	(0.069)
Range targeter		-0.105***		-0.180***		-0.204***
		(0.031)		(0.025)		(0.023)
Commodity exporter		0.075**		0.055*		0.069**
		(0.038)		(0.032)		(0.030)
Constant		0.425***		0.595***		0.730***
		(0.070)		(0.073)		(0.076)
Observations	801	801	715	715	627	627
Country FE	Yes		Yes		Yes	

Heteroskedasticity robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5
Headline inflation - non-overlapping windows

VARIABLES	(1) $\hat{\sigma}^{\pi}$ (2yr)	(2) $\hat{\sigma}^{\pi}$ (2yr)	(3) $\hat{\sigma}^{\pi}$ (4yr)	(4) $\hat{\sigma}^{\pi}$ (4yr)	(5) $\hat{\sigma}^{\pi}$ (6yr)	(6) $\hat{\sigma}^{\pi}$ (6yr)
GDP (2yr)	-0.161	-0.031				
	(0.122)	(0.042)				
MP activity (2yr)	0.182	0.229				
	(0.221)	(0.145)				
TOT vol (2yr)	0.004	0.003				
	(0.021)	(0.014)				
Openness (2yr)	-0.509	-0.160				
	(0.456)	(0.202)				
GDP (4yr)			0.267	0.003		
			(0.180)	(0.065)		
MP activity (4yr)			0.194	0.254		
			(0.324)	(0.210)		
TOT vol (4yr)			0.029	0.020		
			(0.045)	(0.024)		
Openness (4yr)			0.131	0.091		
			(0.725)	(0.312)		
GDP (6yr)					-0.222	-0.042
					(0.209)	(0.077)
MP activity (6yr)					0.291	0.520**
					(0.454)	(0.255)
TOT vol (6yr)					0.070	0.047
					(0.071)	(0.031)
Openness (6yr)					-0.816	-0.078
					(0.649)	(0.321)
Range targeter		-0.128		-0.169*		-0.209*
		(0.087)		(0.098)		(0.119)
Commodity exporter		0.197*		0.079		-0.034
		(0.104)		(0.118)		(0.138)
Constant		0.661***		0.698**		0.639*
		(0.190)		(0.317)		(0.344)
Observations	109	109	55	55	44	44
Country FE	Yes		Yes		Yes	

Heteroskedasticity robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6
Serial correlation test - non-overlapping windows

	Corr	F-stat	p-value
2yr window	-0.382	4.497	0.060
4yr window	-0.460	0.133	0.723
6yr window	-0.397	0.779	0.398

Wooldridge (2002) test. H0: corr=-0.5

Table 7
UCSV Inflation volatility estimates

	(1)	(2)	(3)
VARIABLES	v_t	h_t	g_t
GDP	-0.0859	0.0010	0.0218
	(0.0517)	(0.0109)	(0.1309)
MP Activity	0.2291**	0.0341	0.2638**
	(0.0803)	(0.0206)	(0.0953)
TOT	0.0005	0.0002*	0.0009
	(0.0006)	(0.0001)	(0.0016)
Openness	-0.1655	-0.1280***	-0.2582
	(0.1593)	(0.0381)	(0.2749)
Observations	802	802	802
Country FE	Yes	Yes	Yes

Heteroskedasticity robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figures

Figure 1
Headline and Core Inflation Volatility

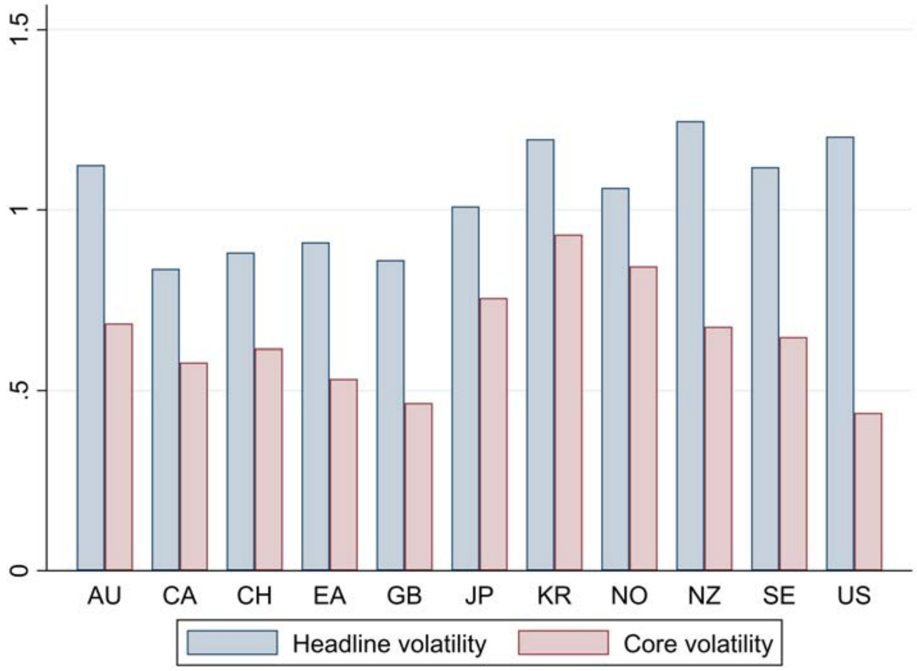
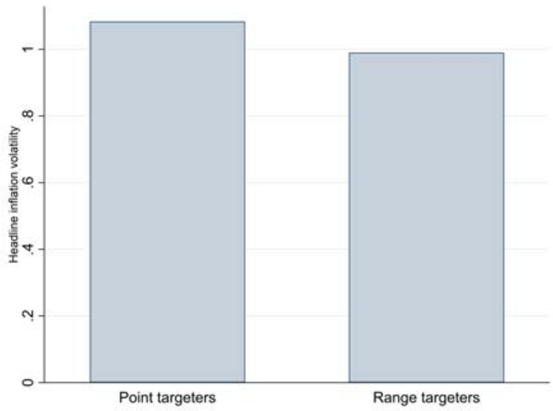


Figure 2
Inflation Volatility groups

(a) Range vs Point targeters



(b) Commodity exporters

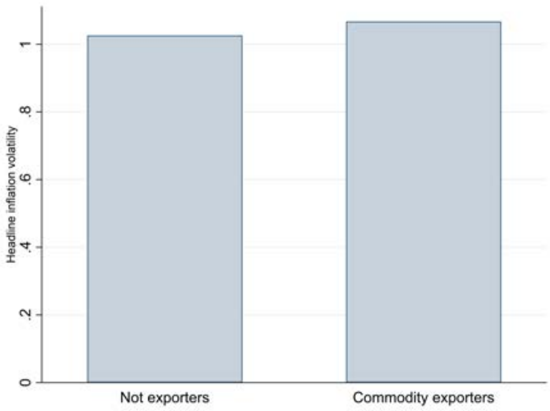


Figure 3
Inflation volatility and size

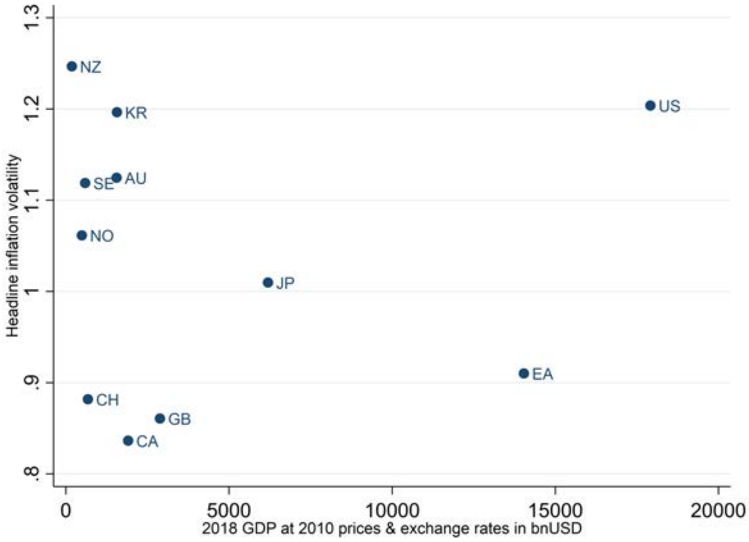


Figure 4
Inflation volatility and Monetary Policy Activity

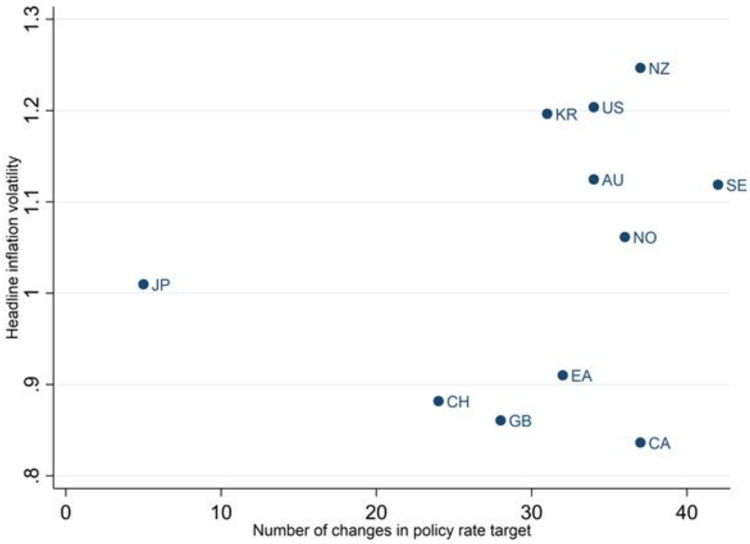


Figure 5
Stochastic inflation volatility

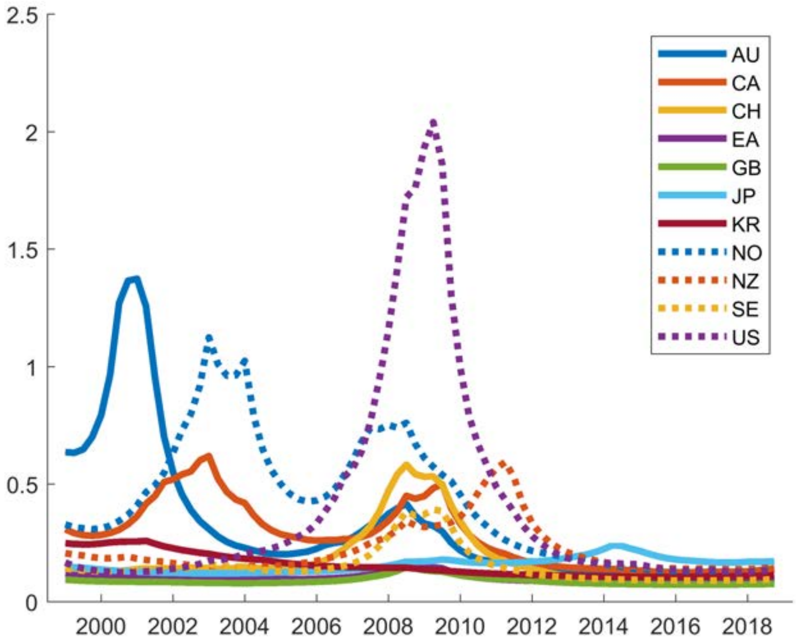
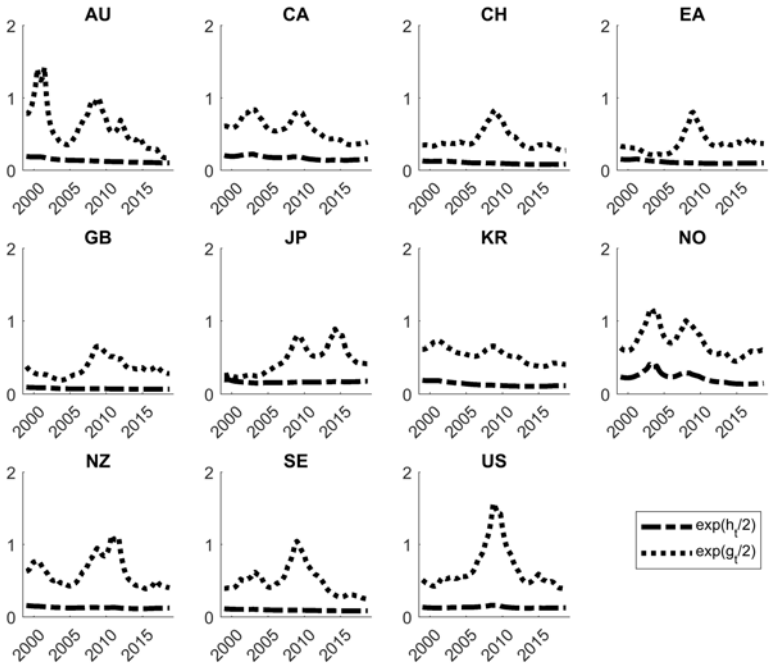


Figure 6
Inflation volatility decomposition



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Appendix

Table 8
Headline Inflation log std - cross section

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2018 USD GDP	-0.722	0.456							
	(4.906)	(4.113)							
Range targeter	-0.071		-0.048						
	(0.046)		(0.046)						
MP activity	0.002			0.002					
	(0.001)			(0.002)					
Commodity exporter	0.036				0.020				
	(0.054)				(0.049)				
GDP_USD std						0.000			
						(0.000)			
URX std							0.015		
							(0.065)		
TOT std								0.010	
								(0.007)	
Openness									-0.064
									(0.062)
Constant	0.685***	0.709***	0.733***	0.649***	0.704***	0.702***	0.697***	0.668***	0.752***
	(0.046)	(0.030)	(0.023)	(0.052)	(0.028)	(0.029)	(0.063)	(0.043)	(0.046)
Observations	11	11	11	11	11	11	11	11	11

Heteroskedasticity robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9
Headline Inflation seasonally adjusted - cross section

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2018 USD GDP	-2.022	0.898							
	(10.249)	(8.172)							
Range targeter	-0.156		-0.106						
	(0.100)		(0.092)						
MP activity	0.000			0.001					
	(0.002)			(0.004)					
Commodity exporter	0.090				0.030				
	(0.115)				(0.099)				
GDP_USD std						0.000			
						(0.000)			
URX std							0.017		
							(0.131)		
TOT std								0.022	
								(0.013)	
Openness									-0.169
									(0.107)
Constant	1.088***	1.044***	1.096***	1.005***	1.037***	1.032***	1.032***	0.947***	1.158***
	(0.103)	(0.060)	(0.045)	(0.126)	(0.058)	(0.058)	(0.126)	(0.086)	(0.081)
Observations	11	11	11	11	11	11	11	11	11

Heteroskedasticity robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10
GDP deflator - cross section

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2018 USD GDP	-73.975	-99.013*							
	(39.790)	(46.481)							
Range targeter	-1.512		-0.093						
	(0.856)		(0.824)						
MP activity	-0.013			0.035					
	(0.029)			(0.028)					
Commodity exporter	2.422**				1.999**				
	(0.882)				(0.809)				
GDP_USD std						-0.005			
						(0.003)			
URX std							-1.790*		
							(0.946)		
TOT std								0.318*	
								(0.148)	
Openness									-0.039
									(1.000)
Constant	2.218*	2.104***	1.715*	0.602	0.945***	2.064***	3.336**	0.242	1.698*
	(0.940)	(0.585)	(0.764)	(0.617)	(0.124)	(0.585)	(1.204)	(0.414)	(0.751)
Observations	11	11	11	11	11	11	11	11	11

Heteroskedasticity robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 11
Headline rolling window - time period sensitivity

	(1)	(2)	(3)
VARIABLES	Pre crises	Crises dummy	Post crises
GDP (4yr)	-0.05	0.25	-0.57
	(0.20)	(0.26)	(0.64)
MP activity (4yr)	0.96	0.07	0.06
	(0.59)	(0.30)	(0.31)
TOT vol (4yr)	0.00	0.01	-0.02*
	(0.06)	(0.04)	(0.01)
Openness (4yr)	-3.21**	0.07	-1.07
	(1.32)	(0.49)	(4.14)
Crises*GDP (4yr)		0.10**	
		(0.03)	
Crises*MP activity (4yr)		0.04	
		(0.25)	
Crises*TOT vol (4yr)		0.01	
		(0.02)	
Crises*Openness (4yr)		0.29**	
		(0.10)	
Constant	1.93**	0.38	2.06
	(0.74)	(0.50)	(2.34)
Observations	231	715	176
Country FE	Yes	Yes	Yes

Heteroskedasticity robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12
Headline inflation - rolling windows - HAC standard errors

VARIABLES	(1) $\hat{\sigma}^{\pi}$ (2yr)	(2) $\hat{\sigma}^{\pi}$ (2yr)	(3) $\hat{\sigma}^{\pi}$ (4yr)	(4) $\hat{\sigma}^{\pi}$ (4yr)	(5) $\hat{\sigma}^{\pi}$ (6yr)	(6) $\hat{\sigma}^{\pi}$ (6yr)
GDP (2yr)	0.167	0.016				
	(0.216)	(0.043)				
MP activity (2yr)	0.168	0.209*				
	(0.119)	(0.110)				
TOT vol (2yr)	0.047***	0.042***				
	(0.017)	(0.015)				
Openness (2yr)	-0.362	0.084				
	(0.419)	(0.177)				
GDP (4yr)			0.372	0.024		
			(0.338)	(0.054)		
MP activity (4yr)			0.135	0.140		
			(0.161)	(0.165)		
TOT vol (4yr)			0.045**	0.034**		
			(0.021)	(0.015)		
Openness (4yr)			0.272	0.170		
			(0.518)	(0.204)		
GDP (6yr)					0.419	0.026
					(0.530)	(0.059)
MP activity (6yr)					0.041	0.047
					(0.175)	(0.196)
TOT vol (6yr)					0.045	0.025
					(0.028)	(0.016)
Openness (6yr)					0.707	0.194
					(0.512)	(0.208)
Range targeter		-0.105		-0.180**		-0.204***
		(0.073)		(0.079)		(0.077)
Commodity exporter		0.075		0.055		0.069
		(0.085)		(0.094)		(0.094)
Constant		0.425***		0.595***		0.730***
		(0.162)		(0.218)		(0.252)
Observations	801	801	715	715	627	627
Country FE	Yes		Yes		Yes	

HAC Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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