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Deflation expectations*

By Ryan Banerjee[1] and Aaron Mehrotra[2]

Abstract

We analyse the behaviour of inflation expectations during periods of deflation, using a large cross-country data set of individual professional forecasters' expectations. We find some evidence that expectations become less well anchored during deflations. Deflations are associated with a downward shift in inflation expectations and a somewhat higher backward-lookingness of those expectations. We also find that deflations are correlated with greater forecast disagreement. Delving deeper into such disagreement, we find that deflations are associated with movements in the left-hand tail of the distribution. Econometric evidence indicates that such shifts may have consequences for real activity.

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1. Introduction

The widespread shift to a low inflation environment after the Great Financial Crisis (GFC) of 2008–09, and Japan's earlier experience, brought policymakers' concerns about deflation back to the fore. While the previous literature has proposed theoretical frameworks for the behaviour of inflation and inflation expectations during deflationary periods (Benhabib et al (2002) and Busetti et al (2014)), in general empirical research on inflation expectations has not focused explicitly on periods of falling prices. For example, Ehrmann (2015) and IMF (2016) cover episodes of low inflation but do not focus on periods of deflation.

Analysing the behaviour of inflation expectations during deflations is relevant for a number of reasons. Such expectations matter for wage and price setting and any second-round effects from falling prices. The degree of anchoring of expectations is thus likely to affect both the depth and duration of deflation (see eg Fuhrer (2017), Nishizaki et al (2014) and Williams (2009)). A downward drift in inflation expectations and risks thereof have been one rationale for the use of unconventional monetary policies in the euro area (eg Draghi (2015)). Avoiding deflation was also a significant factor behind the accommodative US monetary policy stance of the early 2000s (eg Greenspan (2004)).

There are divergent views on the dynamics of deflation, in part driven by historical evidence relating to deflationary spells before the Second World War.[3] On the one hand, the deflationary spell experienced during the Great Depression suggests that economies could be at risk of adverse deflations, with aggregate demand deficiencies reflected in falling price levels and economic slack. On the other hand, the more benign deflationary experience of the latter part of the 19th century provides less evidence that deflation leads to strong negative feedback loops with aggregate demand (Bordo and Filardo (2005) and Borio et al (2015)).[4] This unsettled debate may also be evident in a wider dispersion of professional forecasts during deflations.

In this paper, we analyse the behaviour of inflation expectations during deflationary episodes. In particular, we investigate whether expectations become less well anchored. If expectations are well anchored, they should remain relatively stable at a given level over time, with only minor disagreements across forecasters.

We use surveys of professional forecasters from Consensus Economics at the forecaster level for headline inflation in the next calendar year. The data comprise forecasts for inflation in 43 advanced and emerging market economies. The global nature of the data set is highly relevant, as deflations have not been limited to advanced economies – 30 of the 47 deflationary episodes identified in our data set occur in emerging market economies (EMEs), mostly in Asia and central and eastern Europe. We first provide some stylised facts about the deflationary episodes themselves and the behaviour of professional forecasters' inflation expectations during periods of falling prices. Then, we formally examine whether there is evidence

3 See Burdekin and Siklos (2010) and Smith (2006) for an overview of the empirical evidence relating to deflation, including the phenomenon of debt deflation.

4 See, however, Eichengreen et al (2017), who use producer price inflation and find stronger evidence of the damaging effects of deflation on growth.

that deflation has affected the level of inflation expectations and forecast disagreement, ie two measures of the anchoring of inflation expectations.

We also examine how the monetary policy regime – as well as potential constraints in the form of the zero lower bound (ZLB) – influence inflation expectations during deflations. The behaviour of inflation expectations depends on the expected reaction (or lack) of monetary policy. For example, in inflation targeting (IT) regimes, monetary policy may be expected to address deflation concerns more aggressively than in regimes operating with less explicit inflation mandates. The distance of interest rates from the ZLB could also affect inflation expectations. For example, deflations occurring at times of near-zero short-term interest rates could have different dynamics from other deflations due to perceived constraints on monetary policy. Our paper provides evidence concerning these different dimensions.

We report a number of findings which, taken together, suggest that inflation expectations become less well anchored during deflations. First, deflations are associated with a downward shift in the level of inflation expectations. As we study relatively short-term inflation expectations, uncovering a level effect may not be surprising per se. However, we also find some evidence that deflation renders the levels of inflation expectations more dependent on lagged inflation rates, ie expectations become more backward-looking. Second, deflations lead to greater forecast disagreement. This effect remains after controlling for the deviation of inflation from the inflation target, and controlling for periods of low positive inflation, suggesting that deflation has an effect on disagreement which is over and above that caused by deviations from explicit central bank targets or simply low inflation. Whereas Mankiw et al (2004) document that the dispersion of inflation forecasts is increasing in the level of actual inflation outcomes, we uncover a U-shaped relationship when deflations are included: forecast disagreement rises with the absolute levels of both inflation and deflation outcomes. Third, greater forecast disagreement and level shifts in expectations do not only arise in the context of the ZLB, as their links with deflation also manifest themselves strongly when periods of near-zero interest rates are excluded from the analysis.

As we find stronger forecast disagreement to be a prominent feature of deflations, we delve deeper into the tails of the forecast distribution. Doing so, we find that deflations are associated with greater backward-lookingness in expectations especially in the left-hand tail of the forecast distribution. We investigate the macroeconomic impact of negative shifts in the left-hand tail with a panel vector autoregressive model. The results indicate that such shifts lead to greater disagreement over forecasts for GDP growth but also to temporarily lower output gap and inflation outcomes, suggesting that they have consequences for real activity.

Our paper is related to different strands of literature. It adds to the vast and expanding literature that uses surveys to analyse the anchoring of expectations (eg Levin et al (2004), Kozicki and Tinsley (2012), Mehrotra and Yetman (2017) and Yetman (2017a)). It is also related to research on inflation forecast disagreement (eg Mankiw et al (2004), Capistran and Timmermann (2009), Dovern et al (2012) and Siklos (2013)). And it is related to papers that analyse the implications of price dispersion and forecast disagreement (eg Andrade et al (2015), Huizinga (1993) and Nakamura et al (2017)). Recently, Wiederholt (2015) has shown that heterogeneous inflation expectations render deflation spirals less severe at the ZLB but also reduce the effectiveness of forward guidance policies. Nakata (2017) finds that greater uncertainty regarding the effects of exogenous shocks at the zero lower bound exacerbates output declines during recessions.

Our paper is also related to research on the empirical behaviour of inflation expectations during the post-GFC period. Ehrmann (2015) analyses the anchoring of expectations when inflation is below the central bank's target while the IMF (2016) evaluates changes in anchoring both over time and conditional on monetary policy. Similarly, Blanchard et al (2015) and Blanchard (2016) document changes in the anchoring of expectations over long time periods, including in the post-GFC years. The Bank of Japan (2016) evaluates the behaviour of various measures of inflation expectations after the introduction of quantitative and qualitative monetary easing (QQE) in April 2013. Natoli and Sigalotti (2017a, 2017b) propose novel techniques based on the distribution of financial market data to examine the anchoring of inflation expectations during the post-GFC period. Buono and Formai (2016) use time-varying parameter regressions to examine whether long-term survey expectations react to short-term forecasts in major advanced economies, including in the aftermath of the GFC. And Kenny and Dovern (2017) use data from Surveys of Professional Forecasters to analyse how the distribution of long-run inflation expectations has changed in the euro area after the GFC. To our knowledge, no empirical study has previously focused explicitly on the behaviour of expectations during deflations in a large sample of countries.

This paper is structured as follows. The next section describes the data and presents some data-based stylised facts on inflation outcomes and expectations. Section 3 discusses the methodology used to examine the behaviour of expectations. This is followed in Section 4 by a formal investigation of how deflation affects the behaviour of inflation expectations. In the same section, we also analyse the macroeconomic effects of shifts in the tails of the forecast distribution. We consider various extensions and robustness tests in Section 5. Concluding comments are provided in Section 6.

2. Data and stylised facts on deflationary episodes

We use surveys of professional forecasters from Consensus Economics. These data are available for a relatively long history and are collected in a comparable fashion across a large number of countries, both advanced and emerging. Having a global data set is essential for the analysis, given the large number of deflation episodes in emerging market economies. Regarding the favourable forecasting performance of subjective expectations, Faust and Wright (2013) find that survey measures of inflation expectations tend to improve the forecasts that come from a large number of different forecasting models.

Each month, Consensus Economics polls a panel of experts from public and private economic institutions, mostly investment banks and research institutions, about their predictions for the main macroeconomic variables for the current and next calendar year. Our analysis uses the fixed event forecasts for the next calendar year.[5] Although our study focuses on relatively short-term expectations, changes in

5 At these forecast horizons, forecasters have not yet observed inflation outcomes for the time period being forecast.

short-term inflation expectations may well spill over to those at longer horizons as Buono and Formai (2016) document for the euro area, potentially affecting the credibility of monetary policy. Moreover, for the setting of monetary policy, the most relevant horizon is arguably related to the frequency with which most prices and wages are adjusted, and hence has an important impact on inflation dynamics. Indeed, Fuhrer (2017) finds that short-term expectations play a quantitatively important role for actual inflation outcomes in estimated Phillips curves for Japan and the United States.[6]

On the use of fixed event forecasts, we note that forecasts based on fixed horizons are often easier to use in empirical applications, and some studies approximate fixed-horizon forecasts with a weighted average of two fixed-event forecasts made for different periods (eg Dovern et al., 2012; Gerlach, 2007; Siklos, 2013). However, this approach results at times in significant approximation errors (see Yetman (2017b)), and Kortelainen et al (2011) note that the induced moving average process affects the properties of the data. Moreover, some central bank publications report fixed event inflation forecasts (see eg Bank of Canada (2017, p. 22).

Our data cover 43 economies, 12 advanced and 31 emerging. The length of the data set depends on the availability of inflation forecast data. For advanced economies, the data start earliest in 1990, yielding a maximum of 319 monthly observations per country (see Annex Table A1 for details). For emerging markets, the starting dates vary by region. For most countries in emerging Asia, the data start in late 1994; for Latin America in 2001; and for Central and Eastern Europe in 2007. The number of forecasters varies both across countries and within the same country across time. The average number of forecasters in the country-specific samples vary from 8 in Lithuania to 30 in the United Kingdom; in the full sample, the average number of forecasters per country is 15.

Our inflation data are for headline consumer price inflation (CPI, year on year).[7] While developments in core inflation would also be interesting, expectations data are not widely available for this measure. Moreover, for some EMEs where volatile components such as food comprise a large share of the consumption basket, developments in core inflation may be less relevant than those in headline inflation (eg Anand et al (2015)).

We focus on deflation episodes characterised by negative headline inflation rates (year on year) for at least six consecutive months. Furthermore, a country is regarded as exiting the deflation episode only in the third consecutive month of positive inflation rates that follow deflation. This classification ensures that very short bouts of negative inflation rates do not count as individual deflation episodes. Moreover, it avoids longer deflation periods being classified as several shorter ones, if they are interrupted only by one or two months of positive inflation rates. In the empirical analysis, we also consider "persistent" deflation episodes that comprise a minimum of twelve consecutive months of negative headline inflation rates.

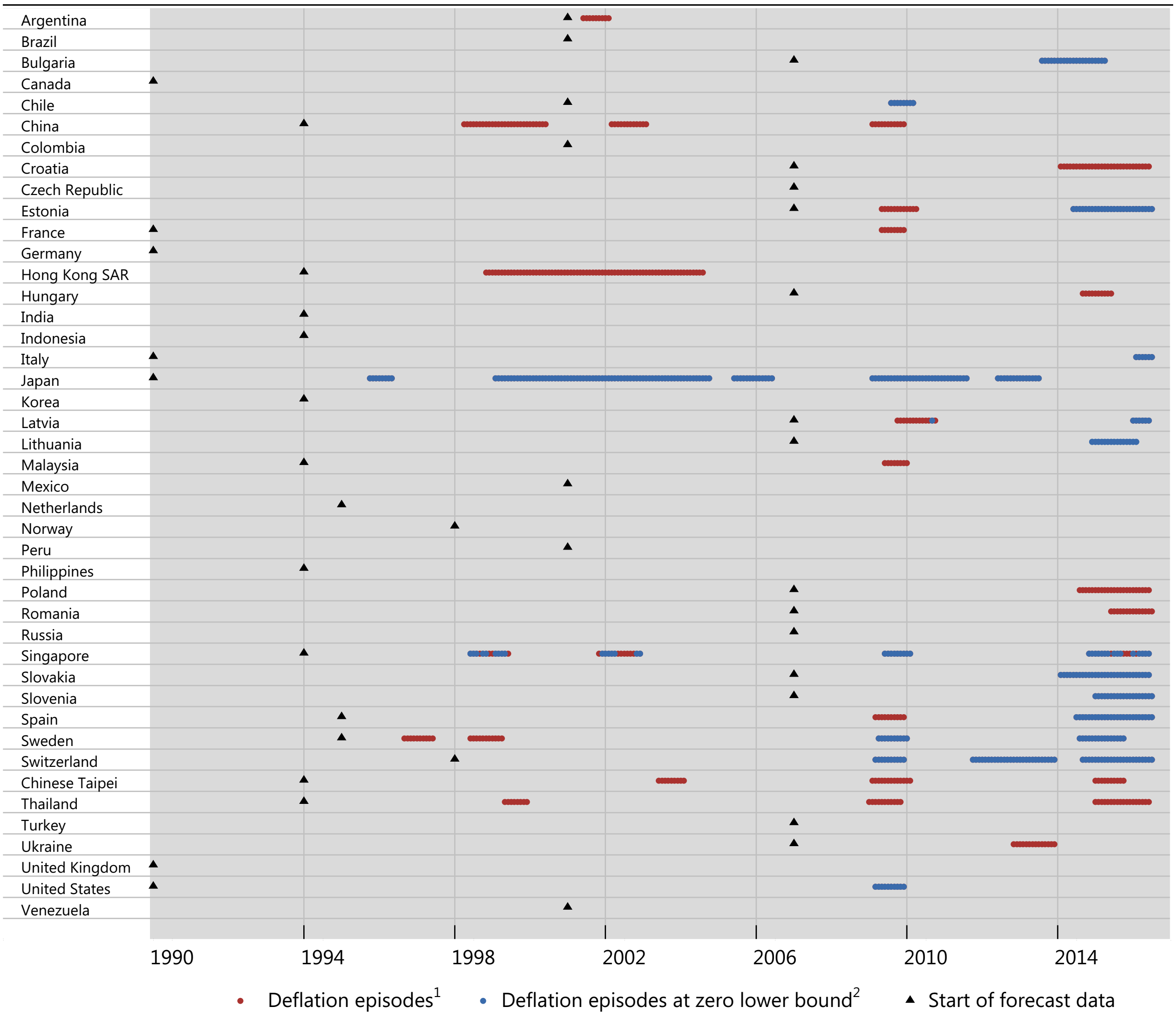
[6] Longer-term forecasts, such as inflation over the next five years, are also available from Consensus, but such surveys are conducted and published only twice a year. Moreover, it is not possible to compute measures of forecast disagreement for the longer-term forecasts, as only the mean forecasts are published.

[7] A partial exception is the United Kingdom, where inflation refers to retail price (RPIX) inflation until 2004 and CPI inflation thereafter.

The 47 deflation episodes identified in our sample are shown in Graph 1. Three periods with greater occurrence of deflations stand out. First, various Asian economies experienced deflation around the time of the Asian financial crisis: Hong Kong SAR, mainland China, Chinese Taipei, Singapore and Thailand. Japan also experienced a long spell of deflation as its domestic banking crisis occurred. The second, more global, bout of deflations took place during the GFC. The third relatively widespread period of falling prices occurred in 2014–15, affecting many European countries but also some emerging economies in Asia. Over time, deflations were increasingly associated with near-zero interest rates (blue lines in Graph 1).

Deflation episodes

Graph 1



[1] Negative headline consumer price inflation (CPI, year on year) for at least six consecutive months. A deflation episode ends if subsequently at least three consecutive months of positive inflation rates occur. [2] Deflation episodes occurring when policy rates are at or below 0.5 per cent. If policy rate data are not available, money market interest rate data are used.

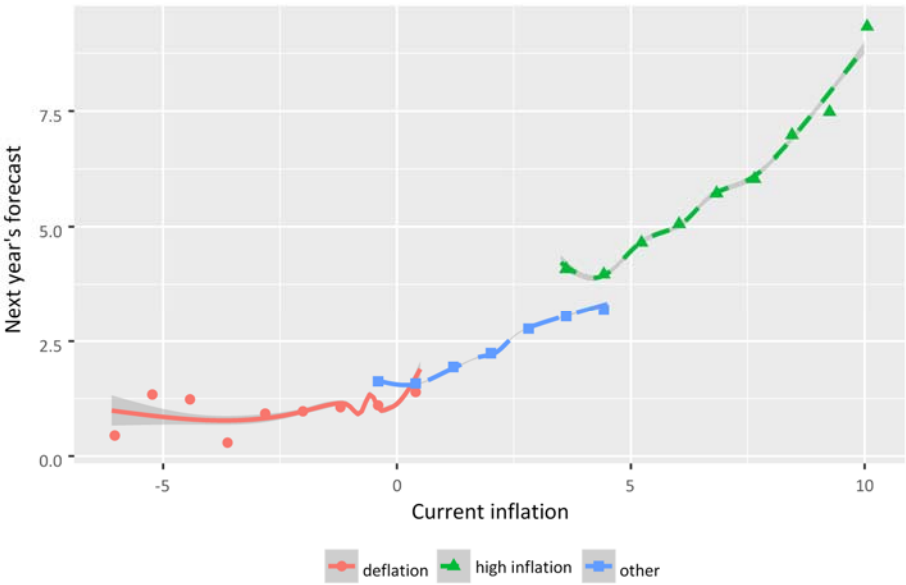
Sources: Consensus; national data; authors' calculations

Overall, the deflation periods are relatively widely dispersed across countries, as in 16 countries deflation episodes occurred only once. 17 deflation episodes took place in advanced economies and 30 in emerging markets, while 11 occurred in countries that were part (or later became part) of the euro area. Hong Kong SAR experienced the lowest inflation outcome within a single deflation episode in the sample (–6.1%). On average the minimum inflation outcome across all the different deflation episodes was –1.7%. Annex Table A2 shows details of the identified deflations, including their length and the minimum inflation outcomes and levels of expectations during these time periods.

Similarly to deflations, we also classify periods of relatively high inflation in the analysis. We define an economy to have high inflation if the headline inflation rate is above four per cent for at least six consecutive months.[8] Furthermore, the country only exits a high inflation episode in the third consecutive month of below-four-percent inflation rates. In our analysis, we omit as outliers all observations with inflation rates exceeding 10%.

Graph 2 shows simple graphical evidence about the relationship between inflation outcomes and the level of forecasts. We divide the sample into twenty buckets based on inflation outcomes and show the average level of next year's forecast within each bucket. Furthermore, we distinguish by colour the different inflation environments using the definitions specified above: deflations, high inflations and other periods.

Level of inflation forecasts and current inflation outcomes | Graph 2



Notes: The graph shows the average inflation forecast for the next calendar year (y-axis) for each of the twenty buckets of inflation outcomes (x-axis). The smoothed lines show results from a generalised additive model between the two variables.

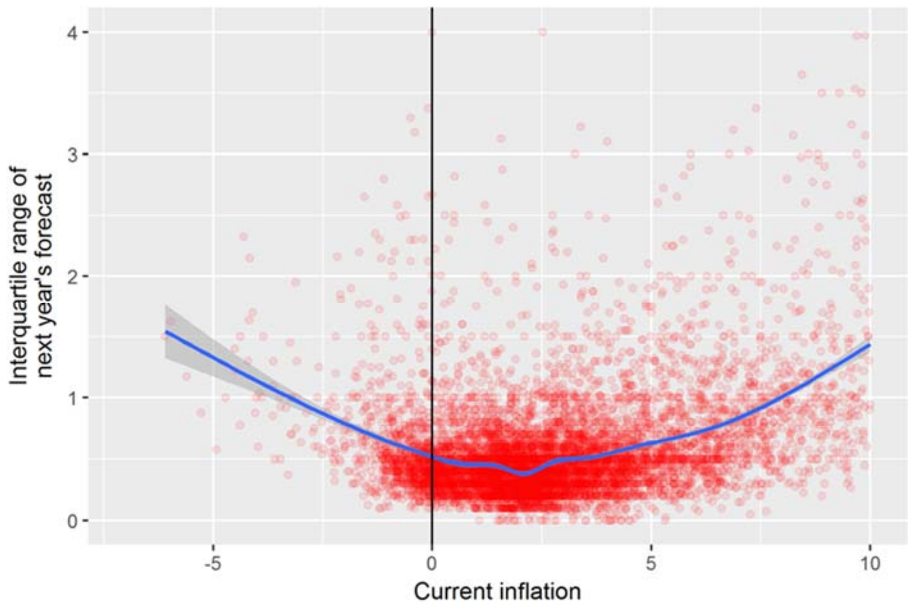
Sources: Consensus; authors' calculations.

[8] An inflation rate of 4% may seem too low a threshold for relatively high inflation, given that our sample includes many EMEs. However, the sample periods for EMEs typically start only after major disinflation processes. Using a threshold of 4% also allows for symmetry in the definition of the episodes, given that inflation targets are often defined to be in the neighbourhood of 2%. Our results are similar when high inflation thresholds of 5% or 6% are considered.

Not surprisingly, Graph 2 suggests that deflations are associated with lower levels of expectations than other environments. Yet, the average expectation for the next calendar year remains positive for all inflation buckets during deflation periods (see also Annex Table A2 for evidence on individual deflation episodes). This contrasts with high inflation periods where the forecasts appear to track inflation outcomes more closely. The relatively limited downward shift of expectations during deflations is consistent with Blanchard et al (2015) and Blanchard (2016) who find that well-anchored expectations helped avoid outright deflation spirals in post-GFC years despite large unemployment gaps. Coibion and Gorodnichenko (2015) argue that a rise in commodity prices during 2009–11 raised inflation expectations and helped avoid major disinflation despite the marked slowdown in activity.

In Graph 3, we plot inflation outcomes together with a measure of forecast disagreement, the interquartile range of next year forecasts. We use a generalised additive model to illustrate the relationship between the variables, shown as the blue line. The generalised additive model fits locally linear regressions, where smoothing is achieved by cubic basis splines (see Hastie and Tibshirani (1990) for more details).

Inflation forecast disagreement and current inflation outcomes Graph 3



Notes: The graph shows month-forecaster observations for current inflation and the interquartile range of next year's forecast. The blue line results from a generalised additive model between the two variables. The shaded area is the 95% confidence interval.

Sources: Consensus; authors' calculations.

Graph 3 suggests that the relationship between inflation outcomes and forecast disagreement is U-shaped. At low and positive inflation rates of around 1–2%, the interquartile range obtains its lowest value, of around 0.5%. The upward-sloping part of the curve during positive inflation rates has been documented in previous research, see eg Mankiw et al (2004). Our results suggest a similar relationship during deflation. In particular, once inflation passes the zero mark and enters negative territory, the interquartile range rises. At an inflation rate of –1.7%, corresponding to the average minimum inflation outcome across the deflation episodes, forecast disagreement is at a similar level as with a positive inflation rate of 6%.[9]

3. Empirical strategy

We formally investigate the behaviour of expectations during deflations by examining the level and dispersion of expectations over time. Both are relevant for the anchoring of expectations. If expectations are well anchored, they should remain relatively stable at a given level over time, with only a small dispersion across forecasters (forecast disagreement; see eg Dovern et al (2012)).[10]

In the analysis of level effects, we follow the approach of papers such as Ball and Sheridan (2004) and Levin et al (2004) to examine whether deflation affects the dependence of the level of expectations on past inflation outcomes, and whether deflation leads to shifts in the level of inflation expectations. Recently, Ehrmann (2015) has used the approach to evaluate whether periods of below and above target inflation affect the anchoring of inflation expectations in ten advanced economies. Lyziak and Paloviita (2017) estimate a similar model to investigate whether the GFC affected the behaviour of inflation expectations in the euro area. Similarly, Blanchard (2016) investigates the dependence of inflation expectations on inflation outcomes in order to examine changes in anchoring over several decades.

Our survey expectations pertain to the relatively short run whereby some effects of currently observed shocks may persist in the forecast horizon. Thus, we effectively test whether deflation makes inflation expectations *more* dependent on past inflation outcomes and/or leads to a *lower* level of expectations than would be the case during periods of positive inflation rates.

We consider a panel fixed effects regression of the type:

$$E_{i,t}(\pi_{c,t+h}) = \alpha_i + \gamma_t + \beta_1 \pi_{c,t-1} + \beta_2 D^{defl}_{c,\,t-1} + \beta_3 D^{defl}_{c,\,t-1} \pi_{c,t-1} + \beta_4 D^{High\,infl}_{c,\,t-1} + \beta_5 D^{High\,infl}_{c,\,t-1} \pi_{c,t-1} + \beta_6 X_{c,t-1} + \varepsilon_{i,t}, \quad (1)$$

where $E_{i,t}(\pi_{c,t+h})$ denotes the expectation of inflation for the next calendar year by forecaster i for country c, formed in period t. Due to the use of next calendar year forecasts, we only consider horizons $12 \leq h < 24$. $\pi_{c,t-1}$ is lagged inflation. $D^{defl}_{c,\,t-1}$ is a dummy variable that obtains a value of one if an economy is in deflation in period t-1 and zero otherwise (see the definition of deflation episodes in Section 2). $D^{High\,infl}_{c,\,t-1}$ is a similarly specified dummy variable for high inflation periods. $X_{c,t-1}$ is a vector of additional lagged country-level control variables that may affect short-term inflation expectations: the output gap $y^{gap}_{c,t-1}$ to capture the effect of economic slack on

9 Providing evidence about the behaviour of actual prices instead of expectations, Gerlach and Kugler (2007) find that higher variance of relative prices is related to both higher inflation and deflation rates in Hong Kong SAR and Japan.

10 Alternative approaches to analysing anchoring include evaluating inflation persistence. In Orphanides and Williams (2005), well-anchored expectations are reflected in less persistent inflation than in the presence of uncertainty about the inflation target (see also Erceg and Levin (2003)). Anchoring could also be examined by studying the response of inflation expectations to news shocks (eg Gürkaynak et al (2010)).

expected inflation[11], the change in the nominal effective exchange rate $\Delta neer_{c,t-1}$ to account for the effect of exchange rate pass-through on prices, and the policy interest rate $i_{c,t-1}$ to control for the effect of monetary policy.[12] α_i and γ_t are forecaster and time fixed effects, respectively. The latter capture common factors such as global commodity price developments that may affect inflation expectations across many countries simultaneously – these may be especially relevant in the recent period where inflation has been low across a large number of economies.[13] We discuss the developments in the time fixed effects explicitly in Section 5. All data sources are given in Annex Table A3.

In the framework described by (1) above, evaluating whether deflation increases the dependence of expectations on past inflation outcomes amounts to testing whether the coefficient β_3 on the interaction variable between deflation and lagged inflation is positive and statistically significant. Similarly, if high inflation renders expectations more dependent on lagged inflation outcomes, the coefficient β_5 on the second interaction variable is statistically significant and positive. In both cases, it would take the central bank longer to get inflation back to target if faced with deflationary or inflationary shocks. Also of interest are the coefficients β_2 and β_4. A statistically significant coefficient on either variable would imply that the level of expected inflation shifts when an economy is going through periods of negative or moderately high inflation rates.

Equation (1) is estimated by ordinary least squares. We use heteroscedasticity-consistent standard errors clustered both by time and by forecaster, using the estimator for linear models with multi-dimensional fixed effects proposed by Correia (2014). Thus, we relax the assumption that the errors are independently distributed within these two dimensions and allow the residuals to be correlated both within the same forecaster over time and across forecasters during the same time period.[14]

The second approach to evaluate the behaviour of inflation expectations focuses on forecast disagreement, ie how much forecasters disagree about the same future inflation outcome. Forecast disagreement has been extensively studied in previous inflation literature, eg Mankiw et al (2004); Capistran and Timmermann (2009); Dovern et al (2012); Siklos (2013); Ehrmann (2015); but not in the context of deflations.

There are various reasons why forecast disagreement could rise during deflation. First, forecasters may be uncertain about the macroeconomic implications of deflation, including its potential interaction with debt. As prices fall, real debt burdens

11 Nishizaki et al (2014) highlight the persistent negative output gaps in the context of Japan's deflation. We construct the output gap as the difference between actual and potential GDP, with potential GDP estimated using a Hodrick-Prescott filter and a conventional smoothing parameter of 1,600 for quarterly data. The data are then converted to monthly frequency by linear interpolation.

12 Money market interest rates are used for periods where policy interest rates are not available.

13 Ciccarelli and Mojon (2010) document the high comovement in inflation rates across OECD countries, and find an error correction mechanism whereby national inflation rates converge to global inflation. They suggest that this feature helps to forecast country inflation. See also Kearns (2016).

14 As a fixed effect is attributed to each forecaster with the same name, there can be too many or too few fixed effects included. If the name of the same forecasting institution changes over time, our estimates could in some cases understate the true effect of the explanatory variables as they may be erroneously attributed to the fixed effects. However, we also note that fixed effects at the forecaster level are not able to capture changes in the characteristics of the forecasting institutions over time. These include modifications to the model that is used for forecasting, as well as the possibility that the individual/team that provides the forecasts in each institution changes over time.

rise, which could lead to lower spending and even defaults (Fisher (1933); see also Borio et al (2015)). Such a dynamic could further exacerbate consumer price deflation dynamics.

Second, and relatedly, forecasters may view the historical evidence of deflations as unsettled. On the one hand, the experience of deflation during the Great Depression suggests that economies may be at risk of adverse deflations with aggregate demand deficiencies reflected in falling price levels and economic slack. On the other hand, the more benign experience of deflation in the latter part of the 19th century provides less evidence that deflation has strong negative feedback loops with aggregate demand (Bordo and Filardo (2005); Borio et al (2015); see, however, Eichengreen et al (2017)).

Third, asymmetries in individual forecasters' costs of over and under predicting inflation could be at play. The model by Capistran and Timmermann (2009) suggests that due to such factors, inflation forecast disagreement varies over time reflecting the level and variance of current inflation.

The estimated equation for forecast disagreement is of the type:

$$disp_{c,t}\left(\pi_{c,t+h}\right) = \alpha_c + \gamma_t + \lambda_1 E_{c,t}(abs(\pi_{c,t+h})) + \lambda_2 D_{c,\,t-1}^{defl} + \lambda_3 D_{c,\,t-1}^{high\,infl} + \lambda_4 X_{c,t-1} + \varepsilon_{c,t}. \quad (2)$$

In (2), $disp_{c,t}\left(\pi_{c,t+h}\right)$ denotes the dispersion (disagreement) of next calendar year forecasts, for forecasts formed at period t for country c. Our benchmark measure of dispersion is the interquartile range, but we also estimate the model using the interdecile range. The second measure is more affected by outlier forecasts, which may be interesting in their own right during deflation periods. α_c and γ_t are country and time fixed effects, respectively. The notations for the dummy variables follow those in Equation (1). Evaluating the impact of deflation (high inflation) outcomes on forecast disagreement amounts to investigating the magnitude and statistical significance of the coefficient estimate λ_2 (λ_3).

In an equation similar to (2), Ehrmann (2015) includes the level of inflation expectations, to allow for the fact that higher inflation tends to be more volatile and therefore might be subject to more disagreement. We modify this by including $E_{c,t}(abs(\pi_{c,t+h}))$, ie the absolute level of median expected inflation in the next calendar year in country c, with the expectation formed in period t. We do so because the U-shape of the smooth regression line in Graph 3 suggests that including the absolute level is a more appropriate specification when deflation periods are included. In particular, incorporating simply the level of expected inflation produces a good fit for the higher inflation periods, for which we have more data points. But when deflation periods are included, the approach would artificially depress the model's predicted dispersion in periods of falling prices and bias the result toward one suggesting that deflation causes higher forecast disagreement.

The vector of lagged control variables $X_{c,t-1}$ in (2) comprises the output gap $y_{c,t-1}^{gap}$, deviations from the inflation target $infl\,gap_{c,\,t-1}$ and its squared term, the policy interest rate $i_{c,t-1}$, the absolute change in the nominal effective exchange rate $abs\left(\Delta neer_{c,t-1}\right)$, the squared change in the policy interest rate $(\Delta i_{c,t-1})^2$, the absolute change in the inflation rate $abs\left(\Delta\pi_{c,t-1}\right)$ and the squared change in the inflation rate $\left(\Delta\pi_{c,t-1}\right)^2$. The squared terms are motivated by the literature on sticky information that suggests that forecast disagreement could rise in response to large changes in macroeconomic variables (Mankiw and Reis (2002); Mankiw et al (2004)). This occurs, as only a fraction of forecasters update their information sets in each period, giving rise to an endogenous rise in forecast dispersion when the economy faces large shocks affecting prices. The inclusion of squared change in the policy rate is also consistent with the empirical study by Dovern et al (2012) for G-7 countries, where the latter variable is used as a proxy for variation in monetary policy.

4. Empirical evidence

In this section, we analyse formally whether deflation has affected inflation expectations. First, we investigate whether there is evidence of unanchoring of inflation expectations, both in terms of the level of expected inflation and forecast disagreement. Second, we evaluate the role of the monetary policy framework and policy constraints posed by the zero lower bound. Finally, we go deeper to the tails of the forecast distribution and analyse the macroeconomic implications of shifts in the left-hand tail of forecast distribution.

4.1. Deflation and the level of inflation expectations

First, we analyse whether deflation affects the level of inflation expectations. The level regressions are estimated using panels of forecaster-level data, yielding over 120,000 observations. We use forecaster and time fixed effects, clustering the standard errors both by forecaster and time period. Periods of inflation rates above 10% are excluded from all estimations in the paper.[15]

The estimates in Table 1 suggest that deflation does affect the level of inflation expectations. Column (1) shows that expectations are somewhat backward-looking in our sample – the coefficient on the lagged inflation term is 0.310. Column (2) adds dummy variables for deflation and high inflation periods, respectively, while Column (3) additionally considers interaction terms of lagged inflation with deflation and high inflation dummy variables, respectively. Thus, the two models examine whether inflation expectations dynamics differ in periods of deflation and high inflation. These estimations suggest that deflations are associated with a downward level shift in expected inflation, by around 0.15 percentage points, as shown by the statistically significant negative coefficients on $D^{defl}_{c,t-1}$. The interaction term between the deflation dummy variable with lagged inflation in Column (3) is positive and economically significant, yet only weakly significant in a statistical sense. The estimates imply that the coefficient on lagged inflation increases by 50% during deflations.[16] Statistical significance is stronger for the interaction between high inflation and lagged inflation.

15 We also exclude all periods with policy rates above 100%, in order to eliminate outliers related to extreme financial market volatility.

16 The finding of somewhat greater backwardness in expectations concurs with other, more anecdotal, evidence. For instance, the Bank of Japan (2017) finds a significant adaptive component of inflation expectations in the Japanese economy. The study attributes this feature in expectations formation to the prolonged deflation such that expectations have not been anchored at 2%. Similarly, Banca d'Italia (2017a) reports that wage contracts in Italy have been increasingly linked to past rather than forecast inflation, which could make it more difficult to return inflation to target.

Level of inflation expectations and deflation

Table 1

Variable	(1)	(2)	(3)	(4)	(5)
$\pi_{c,t-1}$	0.310*** (0.0157)	0.285*** (0.0155)	0.234*** (0.0144)	0.284*** (0.0156)	0.250*** (0.0165)
$D^{defl}_{c,\,t-1}$		–0.155*** (0.0472)	–0.145* (0.0761)		
$D^{defl}_{c,\,t-1}\pi_{c,t-1}$			0.156* (0.0916)		
$D^{High\,infl}_{c,\,t-1}$		0.127*** (0.0360)	–0.230** (0.0981)	0.133*** (0.0359)	–0.177* (0.107)
$D^{High\,infl}_{c,\,t-1}\pi_{c,t-1}$			0.0920*** (0.0213)		0.0761*** (0.0236)
$y^{gap}_{c,t-1}$	0.0511*** (0.0129)	0.0517*** (0.0129)	0.0516*** (0.0129)	0.0516*** (0.0129)	0.0521*** (0.0128)
$\Delta neer_{c,t-1}$	–4.445 (2.921)	–4.511 (2.918)	–4.378 (2.767)	–4.452 (2.909)	–4.431 (2.948)
$i_{c,t-1}$	–0.00621 (0.00430)	–0.00608 (0.00434)	–0.00584 (0.00431)	–0.00622 (0.00441)	–0.00634 (0.00437)
$D^{defl\,long}_{c,\,t-1}$				–0.316*** (0.0566)	–0.300*** (0.0673)
$D^{defl\,long}_{c,\,t-1}\pi_{c,t-1}$					0.0845 (0.0572)
Obs	125,107	125,107	125,107	125,107	125,107
R-squared	0.835	0.836	0.837	0.836	0.837

Notes: Dependent variable is the expectation by an individual forecaster for inflation in the next calendar year. Robust standard errors clustered by forecaster and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (2) and (3) show results when the deflation dummy comprises all deflations; columns (4) and (5) include only persistent deflations. All models include forecaster and time fixed effects.

Results for longer deflations are broadly similar to the shorter ones. Columns (4) and (5) in Table 1 re-estimate Equation (1) using our second definition of deflationary episodes, where negative inflation rates persist for a minimum of twelve consecutive months. Persistent deflations are associated with an economically and statistically significant decline in the level of inflation expectations, by around 0.3 percentage points. At the same time, the interaction between the deflation dummy and lagged inflation is no longer statistically significant. Taken together, our results indicate that deflations affect the level of inflation expectations mainly through level shifts, with somewhat weaker evidence for increased backward-lookingness. These results suggest that deflations make it more difficult to return inflation to target.

The control variables in Columns (1) to (5) obtain coefficients with the expected signs. More positive output gaps are associated with higher levels of expected inflation, with highly statistically significant coefficients. While a faster rate of effective exchange rate appreciation and higher policy rates are associated with a decline in expected inflation, the coefficients are not significantly different from zero.

These results are robust to excluding the period of the GFC (September 2008–December 2009), as shown in Annex Table A4. In particular, when the GFC is excluded, the statistical significance of deflation-induced level shifts and greater backward-lookingness in expectations actually rises (Column (3)).[17]

4.2. Deflation and forecast disagreement

Our estimates show that deflation is also associated with greater forecast disagreement (Table 2). Using the interquartile range as the benchmark measure for disagreement, the coefficient on the deflation dummy in Column (1) is economically and statistically significant even in the presence of a battery of control variables – forecast dispersion rises by around 0.15 percentage points during deflation, compared to other periods. In contrast, high inflation does not lead to a further rise in forecast disagreement, beyond that already captured by a higher level of expected inflation. Indeed, Column (1) shows that when the absolute level of next year's forecast is higher, forecast disagreement is larger.[18]

Does higher forecast disagreement during deflations simply reflect the fact that inflation is below the central bank's target? We include in Column (2) as further control variables the absolute deviation of inflation from the inflation target (the inflation gap in absolute terms) and the squared value of the gap. For countries that specify target ranges, the deviation refers to the distance of inflation from the mid-point of the target range. For economies that do not pursue IT, and for current inflation targeters prior to the adoption of IT, we use the deviation of inflation outcomes from a Hodrick-Prescott filtered trend, with a smoothing parameter of 14,400. We find that the coefficient on the deflation dummy remains robust to the inclusion of such variables, suggesting that deflations affect forecast disagreement beyond the impact of inflation gaps. Column (3) displays results for deflation periods that last a minimum of twelve months. They show that forecast disagreement rises also during the more persistent deflation periods, with a similarly sized coefficient estimate, albeit somewhat weaker statistical significance.

The other control variables in Table 2 obtain the expected signs and are in some cases highly statistically significant. Forecast disagreement rises in response to large changes in policy rates, and is also greater when changes in exchange rates are larger. The response is consistent with a framework where expectations are adjusted infrequently and there are costs to acquire and process inflation, such as a sticky information or rational inattention models.[19] Moreover, forecast disagreement increases as the output gap falls, with the coefficient significant at the 1% level. The sign on the output gap is consistent with the results of Dovern et al (2012) for the G-7 economies. Our results are again robust to excluding the GFC; in this case, the

17 As the inflation expectations data pertain to fixed events (forecasts for next calendar year), the estimated parameters could be affected by the changing forecast horizon within each year. To check whether this influences our results, we estimated the model in Table 1 separately for each month of the year (ie one regression for each forecast horizon). The results are qualitatively similar and are available on request.

18 Including the level of expected inflation instead of the absolute level also results in a statistically significant and positive coefficient (not shown). However, as discussed in Section 3, the absolute level is a more appropriate specification when deflation periods are included.

19 In the context of professional forecasters, the sticky information model could be particularly applicable when adjustments to the information set are considered in a broad sense. For example, there may be costs in updating the parameters of a forecasting model when there are structural changes in the economy (Ballantyne et al (2016)).

rise in disagreement during persistent deflations becomes statistically significant at 5% level (Column (3) in Annex Table A5).

Forecast disagreement

Table 2

Variable	(1)	(2)	(3)	(4)	(5)
$E_{c,t}\left(abs(\pi_{c,t+h})\right)$	0.102** (0.0438)	0.106** (0.0445)	0.102** (0.0432)	0.201*** (0.0709)	0.196*** (0.0687)
$D_{c,\,t-1}^{defl}$	0.154** (0.0614)	0.136** (0.0599)		0.222** (0.0982)	
$D_{c,\,t-1}^{High\,infl}$	–0.0118 (0.0533)	–0.0291 (0.0534)	–0.0342 (0.0556)	–0.0187 (0.0807)	–0.0268 (0.0837)
$infl\ gap_{c,\,t-1}$		0.0424** (0.0194)	0.0483** (0.0199)	0.0767*** (0.0261)	0.0865*** (0.0268)
$(infl\ gap_{c,\,t-1})^2$		–0.000501 (0.00139)	–0.000764 (0.00142)	–0.00100 (0.00158)	–0.00143 (0.00161)
$y_{c,\,t-1}^{gap}$	–0.0315*** (0.0113)	–0.0298*** (0.0110)	–0.0304*** (0.0109)	–0.0610*** (0.0173)	–0.0619*** (0.0172)
$abs\left(\Delta\pi_{c,t-1}\right)$	0.0418* (0.0227)	0.0310 (0.0233)	0.0315 (0.0239)	0.0677 (0.0434)	0.0690 (0.0445)
$\left(\Delta\pi_{c,t-1}\right)^2$	0.00647 (0.00798)	0.00437 (0.00696)	0.00411 (0.00700)	0.00289 (0.0117)	0.00241 (0.0118)
$abs\left(\Delta neer_{c,t-1}\right)$	6.522*** (2.279)	6.166** (2.322)	6.205** (2.377)	10.01*** (3.408)	10.08*** (3.485)
$i_{c,t-1}$	–0.00249 (0.00192)	–0.00293* (0.00159)	–0.00293* (0.00153)	–0.00350 (0.00332)	–0.00353 (0.00319)
$(\Delta i_{c,t-1})^2$	1.33e–05*** (2.49e–06)	1.26e–05*** (2.35e–06)	1.28e–05*** (2.33e–06)	2.03e–05*** (4.25e–06)	2.08e–05*** (4.20e–06)
$D_{c,\,t-1}^{defl\,long}$			0.139* (0.0712)		0.261* (0.140)
Obs	8,061	8,061	8,061	8,061	8,061
R-squared	0.561	0.570	0.568	0.631	0.630

Notes: Dependent variable is the interquartile range of expected inflation for the next calendar year (Columns (1) to (3)) or the interdecile range (Columns (4) and (5)). Robust standard errors clustered by country and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (1), (2) and (4) show results with deflation dummies that comprise all deflations; Columns (3) and (5) include only persistent deflations. All models include country and time fixed effects.

The previous results are also robust to considering a measure of forecast disagreement that incorporates a greater number of outlier forecasts. In particular, Columns (4) and (5) suggest that deflation is associated with an increase in forecast disagreement also when the latter is measured by the interdecile range. The coefficient estimates on the deflation dummy variables are higher in this case.[20]

[20] Similarly to the level regressions, we investigate whether the estimated dynamics vary for the different forecast horizons. The results are qualitatively similar and are available on request.

4.3. The role of monetary policy

Does the monetary policy regime affect the relationship between deflation and inflation expectations? The behaviour of inflation expectations depends on the expected reaction (or lack) of monetary policy. For example, in IT regimes, monetary policy may be expected to address deflation concerns more aggressively than in regimes operating with less explicit inflation mandates, perhaps in order to maintain credibility of the announced targets. We investigate this by dividing the sample into IT economies and those pursuing other regimes, following the classification of countries in the working paper version of Mehrotra and Yetman (2017). We consider both the level of expectations (Table 3) and forecast disagreement (Table 4).

Level of inflation expectations, deflation and monetary policy — Table 3

Variable	IT	Non-IT	IT	Non-IT	Excl. ZLB	Excl. ZLB
$\pi_{c,t-1}$	0.149***	0.248***	0.145***	0.271***	0.214***	0.235***
	(0.0136)	(0.0209)	(0.0132)	(0.0227)	(0.0171)	(0.0201)
$D^{defl}_{c,t-1}$	–0.144*	–0.113			–0.216	
	(0.0766)	(0.0797)			(0.134)	
$D^{High\,infl}_{c,t-1}$	–0.0548	–0.443***	–0.0585	–0.382**	–0.276***	–0.206*
	(0.0843)	(0.161)	(0.0829)	(0.170)	(0.101)	(0.110)
$D^{defl}_{c,t-1}\pi_{c,t-1}$	–0.0193	0.158*			0.180	
	(0.0682)	(0.0853)			(0.115)	
$D^{High\,infl}_{c,t-1}\pi_{c,t-1}$	0.0403**	0.169***	0.0430**	0.146***	0.0905***	0.0701***
	(0.0201)	(0.0359)	(0.0196)	(0.0378)	(0.0219)	(0.0246)
$y^{gap}_{c,t-1}$	0.0288**	0.0449***	0.0297**	0.0453***	0.0324**	0.0328**
	(0.0117)	(0.0159)	(0.0117)	(0.0155)	(0.0148)	(0.0147)
$\Delta neer_{c,t-1}$	–0.0566	–8.555**	–0.0547	–8.733*	–4.476	–4.572
	(0.454)	(4.285)	(0.457)	(4.581)	(2.875)	(3.118)
$i_{c,t-1}$	0.0222**	–0.00555	0.0232**	–0.00601	0.0701***	0.0682***
	(0.0104)	(0.00381)	(0.0105)	(0.00384)	(0.0208)	(0.0209)
$D^{defl\,long}_{c,t-1}$			–0.352*	–0.273***		–0.459**
			(0.189)	(0.0745)		(0.178)
$D^{defl\,long}_{c,t-1}\pi_{c,t-1}$			–0.0548	0.0559		0.0813
			(0.189)	(0.0588)		(0.0796)
Obs	51,554	73,544	51,554	73,544	102,267	102,267
R-squared	0.849	0.848	0.850	0.848	0.832	0.832

Notes: Dependent variable is the expectation by an individual forecaster for inflation in the next calendar year. Robust standard errors clustered by country and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (1), (2) and (5) show results from estimations with all deflations; Columns (3), (4) and (6) include only persistent deflations. All models include country and time fixed effects.

We find little systematic evidence that the monetary policy regime matters for the relationship between deflation and the level of inflation expectations. On the one hand, the negative coefficient on the deflation dummy variable is only (weakly) significant in a statistical sense for IT economies when all deflations are included (Table 3, Columns (1) and (2)). On the other hand, inflation expectations are more backward-looking in non-IT countries during deflations. During persistent deflations

(Columns (3) and (4)), the deflation dummy variable is statistically significant for both inflation targeters and the non-inflation targeters (Table 3, Columns (3) and (4)).

Forecast disagreement, deflation and monetary policy — Table 4

Variable	IT	Non-IT	IT	Non-IT	Excl. ZLB	Excl. ZLB
$E_{c,t}(abs(\pi_{c,t+h}))$	0.101***	0.106*	0.104***	0.102*	0.108**	0.105**
	(0.0249)	(0.0530)	(0.0247)	(0.0517)	(0.0448)	(0.0431)
$D_{c,t-1}^{defl}$	0.0186	0.151**			0.200**	
	(0.0608)	(0.0692)			(0.0942)	
$D_{c,t-1}^{High\,infl}$	–0.0116	–0.0229	–0.0108	–0.0290	–0.0601	–0.0681
	(0.0338)	(0.0857)	(0.0344)	(0.0890)	(0.0558)	(0.0608)
$infl\ gap_{c,t-1}$	–0.00419	0.0583*	–0.00497	0.0672**	0.0401**	0.0476**
	(0.0183)	(0.0302)	(0.0184)	(0.0309)	(0.0197)	(0.0213)
$(infl\ gap_{c,t-1})^2$	0.00615*	–0.00158	0.00593	–0.00198	–0.000714	–0.00104
	(0.00358)	(0.00159)	(0.00374)	(0.00162)	(0.00133)	(0.00142)
$y_{c,t-1}^{gap}$	–0.0302	–0.0270**	–0.0302	–0.0275**	–0.0321**	–0.0329***
	(0.0184)	(0.0130)	(0.0182)	(0.0127)	(0.0120)	(0.0119)
$abs(\Delta\pi_{c,t-1})$	0.0718***	0.00883	0.0728***	0.00653	0.0274	0.0279
	(0.0215)	(0.0292)	(0.0213)	(0.0300)	(0.0271)	(0.0283)
$(\Delta\pi_{c,t-1})^2$	–0.0103***	0.00671	–0.0105***	0.00653	0.00418	0.00391
	(0.00327)	(0.00769)	(0.00319)	(0.00772)	(0.00745)	(0.00756)
$abs(\Delta neer_{c,t-1})$	1.253*	9.126***	1.272*	9.199***	6.134***	6.195***
	(0.622)	(2.300)	(0.620)	(2.385)	(2.167)	(2.234)
$i_{c,t-1}$	0.00117	–0.00316**	0.00123	–0.00315**	0.0186*	0.0191*
	(0.00936)	(0.00134)	(0.00943)	(0.00129)	(0.0107)	(0.0109)
$(\Delta i_{c,t-1})^2$	0.00723**	1.27e–05***	0.00711**	1.29e–05***	1.51e–05***	1.56e–05***
	(0.00318)	(2.26e–06)	(0.00317)	(2.26e–06)	(9.71e–07)	(1.08e–06)
$D_{c,t-1}^{defl\,long}$			0.0971	0.141*		0.248**
			(0.116)	(0.0823)		(0.117)
Obs	3,202	4,847	3,202	4,847	6,733	6,733
R-squared	0.493	0.618	0.495	0.616	0.596	0.594

Notes: Dependent variable is the interquartile range of expected inflation in the next calendar year. Robust standard errors clustered by country and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (1), (2) and (5) show results from estimations with all deflations; Columns (3), (4) and (6) include only persistent deflations. All models include country and time fixed effects.

Being an inflation targeter does make a difference in terms of forecast disagreement. For IT economies, deflations are not associated with a statistically significant increase in forecast disagreement, neither during all deflations nor when only persistent deflations are considered (Table 4, Columns (1) and (3)). This is in contrast to non-inflation targeters that see a greater rise in disagreement both during all deflations and during persistent deflations only (Table 4, Columns (2) and (4)).

Another factor affecting the behaviour of expectations during deflation is the possibility that conventional interest rate policy is constrained. Forecast dynamics and the macroeconomic implications of deflations may be expected to be more adverse if monetary policy is perceived to lack the tools to return inflation to target. In order to examine to what extent interest rates close to zero are affecting the results, we exclude periods with policy interest rates at levels of 0.5% or below from the level regressions (last two columns in Table 3) and from the regressions of forecast disagreement (last two columns in Table 4).

The level shifts in expectations and greater forecast disagreement during deflations do not appear to hinge on the zero interest rate floor. Regarding level shifts, while the coefficient on the deflation dummy does fall in statistical significance when periods of near-zero interest rates are excluded (Column (5) in Table 3), the absolute point estimate actually rises. There is also a large increase in the absolute value of the coefficient on persistent deflation periods ((Column (6) in Table 3).

Similarly, for forecast disagreement, the point estimates on the deflation dummy variables are somewhat higher when periods of near-zero interest rates are excluded from the analysis (Columns (5) and (6) in Table 4). This suggests that disagreement regarding future inflation – potentially reflecting diverging views about the persistence of deflation pressure and its macroeconomic implications – does not arise due to perceived lack of potency of monetary policy.

4.4. Shifting tails of the distribution and macroeconomic implications

As we find a larger forecast disagreement to be a prominent feature of deflations, we further investigate changes in the forecast distribution by focusing on the tails of the distribution. Table 5 evaluates the effects on deflation on both the left and right tails, ie the 10th and 90th percentiles, respectively. In these estimations, the empirical specification follows the one used in the level regressions (Equation (1)).

The results suggest that deflations affect the left-hand tail of the distribution more than that in the right. The interaction between the deflation dummy and lagged inflation is significant at the 10th percentile (Columns (2) and (4)), especially during persistent deflations, but never at the 90th percentile (Columns (5) to (8)). Thus, expectations at the lower tail become more backward-looking during deflations. Similar results are obtained if the 25th and 75th percentiles are used instead; deflation episodes affect expectations in the left-hand tail, but not those in the right (Annex Table A6).

Contrasting with behaviour at the lower tail, expectations at the 90th percentile obtain an economically and statistically significant coefficient on the interaction between high inflation and lagged inflation (Table 5, Columns (6) and (8)). An identical result is obtained at the 75th percentile (Annex Table A6).

Do these shifts in forecast distributions have macroeconomic implications? Regarding forecast disagreement more generally, the primary cost of inflation in a New Keynesian model arises from price dispersion. If inflation forecast disagreement leads to firms setting prices too high or too low, there are costs due to an inefficient allocation of resources. Similarly, if inflation forecast disagreement reflects inflation uncertainty, the signals provided by prices could become blurred and hurt activity. Huizinga (2016) argues that inflation uncertainty could affect investment by increasing uncertainty about the real net present value of capital expenditures. Siklos (2016) suggests that the increase in forecast disagreement could negatively affect the credibility of the central bank. At the same time, greater dispersion does not necessary entail a slower convergence to an inflation target: this is the case if inflation forecasts are broadly centred at the central bank's target, and these mean forecasts are close to those used for price and wage setting, for example.

Tails of forecast distribution and deflation

Table 5

Variable	10th pc	10th pc	10th pc	10th pc	90th pc	90th pc	90th pc	90th pc
$\pi_{c,t-1}$	0.284***	0.249***	0.286***	0.259***	0.340***	0.257***	0.333***	0.272***
	(0.0424)	(0.0372)	(0.0399)	(0.0385)	(0.0409)	(0.0364)	(0.0378)	(0.0360)
$D_{c,t-1}^{defl}$	–0.190*	–0.155			0.0344	0.0120		
	(0.102)	(0.110)			(0.117)	(0.147)		
$D_{c,t-1}^{High\ infl}$	0.134*	–0.0702	0.133*	–0.0338	0.219**	–0.362	0.232**	–0.315
	(0.0778)	(0.195)	(0.0763)	(0.203)	(0.0949)	(0.228)	(0.0939)	(0.224)
$D_{c,t-1}^{defl}\pi_{c,t-1}$		0.141*				0.202		
		(0.0709)				(0.136)		
$D_{c,t-1}^{High\ infl}\pi_{c,t-1}$		0.0553		0.0445		0.150**		0.135**
		(0.0523)		(0.0539)		(0.0595)		(0.0577)
$y_{c,t-1}^{gap}$	0.0868***	0.0866***	0.0876***	0.0880***	0.0204	0.0205	0.0201	0.0216
	(0.0239)	(0.0236)	(0.0240)	(0.0238)	(0.0306)	(0.0299)	(0.0309)	(0.0303)
$\Delta neer_{c,t-1}$	–2.059	–1.919	–1.966	–1.947	–7.332	–7.167	–7.350	–7.339
	(1.797)	(1.674)	(1.795)	(1.827)	(5.047)	(4.850)	(5.077)	(5.182)
$i_{c,t-1}$	–0.00930***	–0.00902***	–0.00952***	–0.00950***	–0.00262	–0.00223	–0.00254	–0.00271
	(0.00325)	(0.00328)	(0.00333)	(0.00345)	(0.00641)	(0.00626)	(0.00645)	(0.00640)
$D_{c,t-1}^{defl\ long}$			–0.291**	–0.148			–0.0821	–0.0945
			(0.134)	(0.129)			(0.144)	(0.110)
$D_{c,t-1}^{defl\ long}\pi_{c,t-1}$				0.191***				0.115
				(0.0596)				(0.0704)
Obs	8,093	8,093	8,093	8,093	8,093	8,093	8,093	8,093
R-squared	0.838	0.838	0.838	0.839	0.845	0.847	0.845	0.847

Notes: Dependent variable is the 10th percentile (Columns (1) to (4)) or the 90th percentile of the forecast distribution (Columns (5) to (8)). Robust standard errors clustered by country and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (1), (2), (5) and (6) show results from estimations where the deflation dummy includes all deflations; Columns (3), (4), (7) and (8) include only persistent deflations. All models include country and time fixed effects.

Source: authors' calculations.

However, in order to examine the macroeconomic implications of forecast behaviour during deflations, one cannot simply examine the effects of greater inflation forecast disagreement. As the relationship between inflation outcomes and forecast dispersion is U-shaped, deflation periods cannot be identified through forecast disagreement alone. Instead, we use the result that there are changes in the left-hand tail of the forecast distribution during deflations which do not affect the right-hand tail. In particular, the higher backward-lookingness in the left-hand tail, even if only weakly statistically significant, can partly account for the higher forecast disagreement during deflations. Moreover, during persistent deflations, backward-lookingness increases only at the left-hand tail of the forecast distribution and not for the entire sample. This can be seen by comparing the interaction coefficients between persistent deflation and inflation outcomes, in particular Column 4 of Table 5 (which is positive and significant even at the 1% level), with Column 5 of Table 1 (which is not significantly different from zero). Thus, in what follows we use shifts in the left-hand tail that are not mirrored by the median, to examine the macroeconomic implications of forecast behaviour during deflations.

There are various economic reasons why shifts in the tails of the forecast distribution could be relevant. One possibility is that some forecasters in the tails are particularly sensitive to incoming information. Taking shifts in their expectations into account could then help policymakers anticipate future inflation. Another issue is that some states of the world – such as deflation and the ZLB – may be particularly costly and monitoring shifts in forecast tails can help avoid their realisation (Evans et al (2015)). Andrade et al (2015) develop a measure called "Inflation-at-Risk" that is associated with the left- and right-hand tails and estimated based on surveys. They find that changes in inflation risks help predict future inflation in the United States and affect changes in the Fed Funds rate. Relatedly, Christensen et al (2012) measure deflation probabilities in the United States using yields on nominal and real Treasury bonds.

To examine the macroeconomic implications of shifts in the left-hand tail, we use a panel vector autoregression with fixed effects, as follows:[21]

$$y_{c,t} = A_1 y_{c,t-1} + A_2 y_{c,t-2} + \cdots + A_p y_{c,t-p} + B z_{c,t} + u_c + e_{c,t}, \tag{3}$$

where $y_{c,t}$ is a vector of k endogenous variables, $z_{c,t}$ contains the exogenous variables, the A_1, ..., A_p and B are coefficient matrices to be estimated; u_c contains the panel fixed effects; and $e_{c,t}$ is assumed to be a white noise error term.

The model incorporates monthly data for country *c* for the output gap, inflation, the policy interest rate, median inflation expectations, the left-hand tail (10th percentile) of the inflation forecast distribution and GDP growth forecast disagreement (the interquartile range), in the same order. All expectations variables refer to the next calendar year. The vector of exogenous variables is comprised of month dummy variables, each obtaining the value of one during a particular month and zero otherwise, to account for the changing forecast horizon over the calendar year. The model is estimated by generalised method of moments (GMM) for an identical sample as the panel regressions in the earlier part of the paper, again excluding observations with inflation rates exceeding 10% or policy rates in excess of 100%. Three lags are included in the VAR. The panel-specific fixed effects are removed through forward orthogonal deviation, with the lags of the transformed variables

[21] The panel VAR is estimated using the pVAR program for STATA by Abrigo and Love (2015).

instrumented by lags of the untransformed variables (see Abrigo and Love (2015) for details).

The usefulness of the VAR in this context hinges on the possibility to identify largely "exogenous" shocks to the lower tail of the inflation forecast distribution and trace their impact on the other variables in the system. For this purpose, after the estimation of the reduced form VAR, we use impulse response analysis and identify the shocks using a recursive identification scheme and a Cholesky decomposition of the variance-covariance matrix. The first three variables in the system form a block of macro variables, and their ordering follows conventional monetary VARs with interest rates ordered last. The slow responsiveness of output to shocks can be justified by rigidities such as predetermined expenditure plans, as in Rotemberg and Woodford (1997), and investment adjustment costs, as in Christiano et al (2005); that of inflation could result from costs of price adjustment, as in Rotemberg (1982). In contrast, we allow changes in professional forecasters' expectations to occur with a shorter delay. However, we restrict the contemporaneous impact of the left-hand tail shock on the median forecast to be zero. Given these assumptions, we can consider the shock to the lower tail a news shock that only affects a fraction of the forecasters instantaneously and does not have real economy implications during the month of the shock. 90% confidence intervals are used to illustrate parameter uncertainty, obtained with 1,000 Monte Carlo draws.

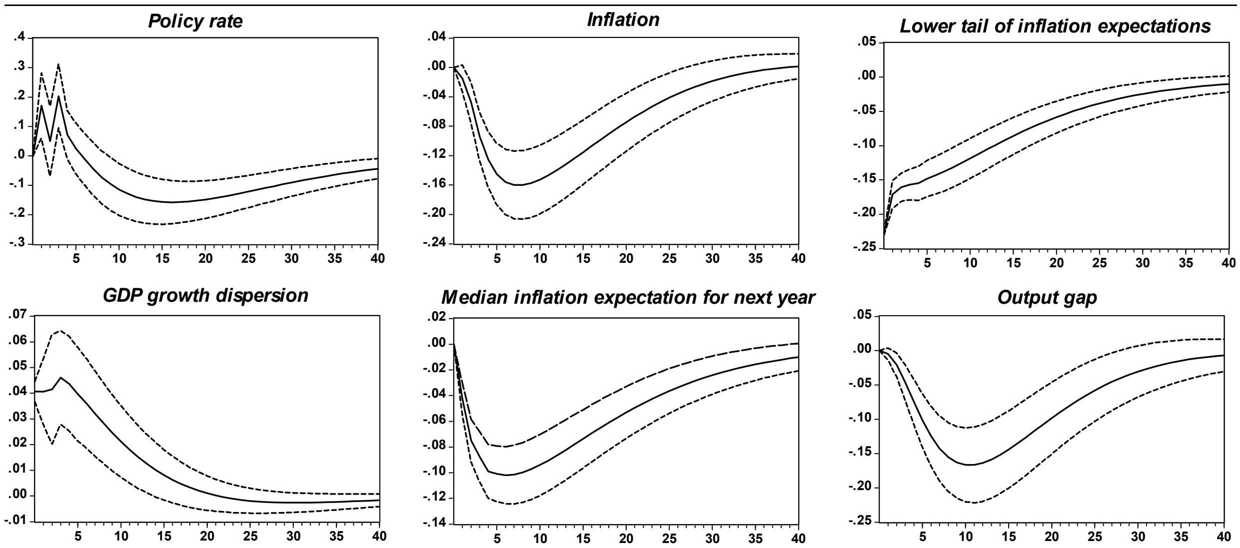
Graph 4 shows the response of all endogenous variables to a negative one standard deviation shock in the left-hand tail of the forecast distribution, until 40 months have passed from the shock. The shock to the left-hand tail is temporary and peters out slowly (upper left-hand panel). The median inflation forecast follows the tail and adjusts downward with a lag. Notably, the shock to the lower tail leads to a temporary increase in GDP forecast disagreement, with the largest effect occurring contemporaneously. Both the output gap and inflation fall. We also consider an alternative ordering of the endogenous variables, reversing the order of the last two: the left-hand tail of the inflation forecast distribution and GDP forecast disagreement. In these estimates as well, GDP forecast disagreement rises in response to a negative shock in the lower tail of inflation forecasts, with a statistically significant impact, after the contemporaneous (imposed) zero response.[22]

The rise in GDP forecast dispersion, together with actual falls in the output gap and inflation, suggests that movement in the left-hand tail of the inflation forecast distribution could have real effects.[23] Various papers document a link between forecast dispersion – or another closely-related proxy for uncertainty – and real activity. Using forecast disagreement measures based on Blue Chip surveys, Ferderer (1993) finds that uncertainty depresses investment activity. Similarly, Guiso and Parigi (1999) use firm-specific uncertainty measures from Italian manufacturing surveys and find that greater uncertainty weakens the response of investment to demand. Banerjee et al (2015) document that increases in GDP forecast disagreement, taken as proxy for demand uncertainty, have a negative effect on business investment in G-7 economies.

22 These results are available from the authors upon request.

23 There could also be effects on financial conditions that subsequently affect real activity. For example, Breach et al (2016) find that inflation uncertainty based on surveys affects the term premium.

Response of variables to negative shock in left-hand tail of forecast distribution Graph 4



Notes: The titles of the panels show the name of the response variable. The underlying shock is a negative one standard deviation shock to the 10th percentile of inflation expectations. The numbers on the x-axis denote the number of months that have passed from the shock.

5. Extensions and further robustness tests

In this section, we consider various extensions and further robustness tests. We distinguish between periods of low inflation and deflation; examine the importance of the macroeconomic context in which the deflation occurs; evaluate common global trends in expectations; and use alternative measures for some of the explanatory variables.

One question is whether our results are indeed driven by deflation, or if they reflect the effect of low inflation on inflation expectations more broadly. Indeed, Ehrmann (2015) finds that below-target inflation weakens the anchoring of inflation expectations. To address this issue, we construct low inflation and persistent low inflation dummy variables similarly to their deflation counterparts, but using a threshold of 1% instead of zero inflation. The identified low inflation periods are thus a superset of the deflation episodes in the sample. We then include both the low inflation and deflation dummy variables in the level and disagreement regressions.

The results in Table 6 indicate that deflation has a significant effect on inflation expectations, beyond that of low inflation alone. In the level regressions, when all episodes of low inflations and deflations are included, only deflation periods lead to statistically significant downward shifts in expected inflation and greater backward-lookingness (Column (1)). And when only persistent episodes of low inflation and deflation are considered, both low inflation and deflation are associated with statistically significant declines in expected inflation, with the deflation dummy obtaining a larger negative coefficient (Column (2)). Similar results are obtained in the disagreement regressions, as shown in Columns (3) and (4). In particular, the deflation dummy obtains larger coefficients than the low inflation dummy even as deviations of inflation from the target and squared deviations are controlled for. However, in the last two columns, the coefficient on the deflation dummy variable is only statistically significant when all deflations are considered.[24]

Low inflation and deflation

Table 6

Variable	Level regression		Disagreement regression	
	All low inflations and deflations	Persistent low inflations and deflations	All low inflations and deflations	Persistent low inflations and deflations
$D^{low\ infl}_{c,\ t-1}$	0.0367 (0.0362)	–0.118*** (0.0428)	0.0603* (0.0355)	0.0816* (0.0431)
$D^{low\ infl}_{c,\ t-1}\pi_{c,t-1}$	–0.102*** (0.0272)	–0.0144 (0.0285)		
$D^{defl}_{c,\ t-1}$	–0.179** (0.0791)	–0.272*** (0.0658)	0.106** (0.0491)	0.0991 (0.0663)
$D^{defl}_{c,\ t-1}\pi_{c,t-1}$	0.252*** (0.0934)	0.109* (0.0604)		
$D^{High\ infl}_{c,\ t-1}$	–0.219** (0.0985)	–0.223** (0.108)	–0.0245 (0.0514)	–0.0311 (0.0544)
$D^{High\ infl}_{c,\ t-1}\pi_{c,t-1}$	0.0873*** (0.0220)	0.0916*** (0.0243)		
Obs	125,107	125,107	8,061	8,061
R-squared	0.837	0.837	0.571	0.570

Notes: The model for level regressions is based on the specification of Columns 3 and 5 in Table 1; that for dispersion regressions is based on specification of Columns 2 and 3 in Table 2. Robust standard errors clustered by forecaster and time (country and time in Columns 3 and 4) in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. All models include forecaster and time fixed effects (country and time fixed effects in Columns 3 and 4).

Next, we examine whether the macroeconomic environment in which deflations occur plays a role. As the first category we consider periods of negative output gaps in order to capture the possibility that demand falling short of supply is contributing to deflation.

We also include episodes of strong exchange rate appreciation in order to capture deflations that occur due to exchange rate pass-through. Exchange rate appreciations have played a role in several deflations, including those in China during the late 1990s-early 2000s (Ha et al (2003)), and in Switzerland in the 2010s (IMF (2012)).

As a third category we consider deflations that occur during or after credit booms. As prices fall, real debt burdens rise, which could lead to lower spending and even defaults (Fisher (1933); see also Borio et al (2015)). Several papers highlight the prominent contribution of credit growth to financial instability (eg Kaminsky and Reinhart (1999); Schularick and Taylor (2012)). Financial distress may further exacerbate consumer price deflation dynamics. Such episodes could represent what

[24] To save space, only the coefficients related to deflation, low inflation and high inflation are shown in Table 6.

Bordo and Filardo (2005) label "bad deflations" – the cause of additional weakness in the economy rather than only a symptom of weak demand.

We classify a deflation episode as belonging to one or more of the different categories if either during the deflation episode or in the twelve months preceding it one or several of the following occurred: (i) the output gap was negative; (ii) the y-o-y change in the nominal effective exchange rate (NEER) was above the 90th percentile; (iii) the credit gap, measured as the deviation of total credit to GDP from its long-run trend, was above 2 percentage points. Previous research has demonstrated the favourable performance of the credit gap as an early warning indicator of financial crises (eg Borio and Drehmann (2009)).

Out of the months that fall within our identified deflation episodes, 52% are associated with high credit gaps, 49% with large exchange rate appreciations, and a total of 99% with negative output gaps. Moreover, given the high shares of months allocated to the various type of deflations, there is significant overlap between them. In particular, 35% of the deflation episode months are classified as both credit gap and NEER deflations; 49% as both NEER and output deflations; and 52% as both credit gap and output deflations.

Type of deflation — Table 7

Variable	Level regressions	Level regressions	Level regressions	Disagreement regressions	Disagreement regressions	Disagreement regressions
$D^{defl\,credit}_{c,\,t-1}$	-0.0675 (0.122)			0.151** (0.0635)		
$D^{defl\,credit}_{c,\,t-1}\pi_{c,t-1}$	0.253** (0.116)					
$D^{defl\,neer}_{c,\,t-1}$		-0.208 (0.142)			0.167* (0.0898)	
$D^{defl\,neer}_{c,\,t-1}\pi_{c,t-1}$		0.267** (0.130)				
$D^{defl\,output}_{c,\,t-1}$			-0.150* (0.0765)			0.139** (0.0600)
$D^{defl\,output}_{c,\,t-1}\pi_{c,t-}$			0.156* (0.0916)			
Obs	117,138	125,107	125,107	7,450	8,061	8,061
R-squared	0.834	0.837	0.837	0.589	0.569	0.570

Notes: Dependent variable is the forecast for next calendar year (Columns (1) to (3)) or the interquartile range of next calendar year forecast (Columns (4) to (6)). *defl credit*, *defl neer* and *defl output* refer to deflations associated with high credit gaps, large exchange rate appreciations, and negative output gaps, respectively. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Models include forecaster and time fixed effects (Columns 1-3), and country and time fixed effects (Columns 4-6). Robust standard errors clustered by forecaster and time (Columns 1-3), and by country and time (Columns 4-6) in parentheses.

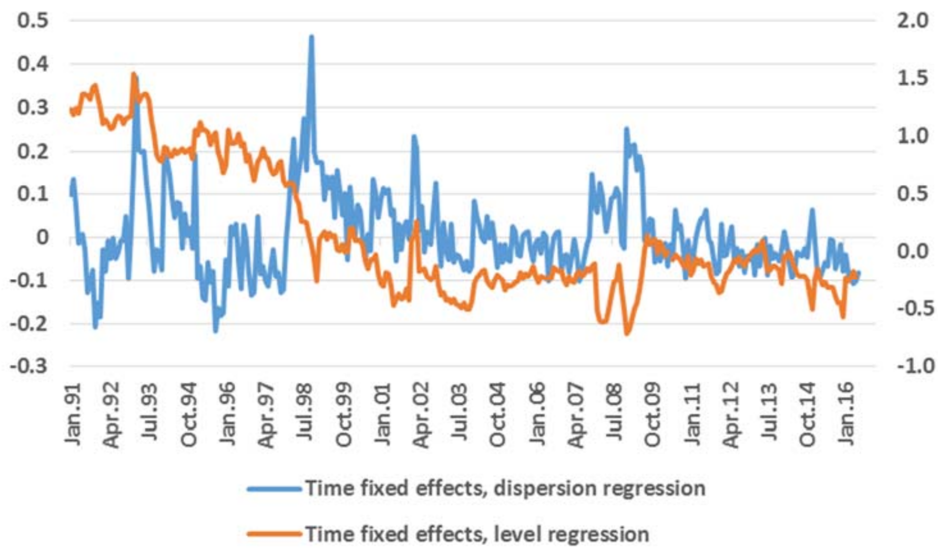
Source: authors' calculations.

All three deflation environments have effects on the level of inflation expectations (Table 7, Columns (1)-(3)). For all three categories, the coefficient on the deflation dummy variable and its interaction with lagged inflation is significant at least at 10% level, suggesting increased backward-lookingness in expectations. The coefficient estimates on the interaction variables are larger for deflations associated with high credit gaps and exchange rate appreciations than for deflations occurring at times of negative output gaps, but the difference is not statistically significant. The result for exchange rate deflations is consistent with IMF (2015) that finds that disinflationary pressure from external factors, such as an appreciating NEER, was feeding into two-year ahead inflation expectations in 2011–14 in European IT countries.

All three environments are also significant drivers of higher forecast disagreement (Columns (4)-(6)). Deflations associated with negative output gaps and high credit gaps have positive coefficients that are significant at the 5% level; exchange rate-related deflations are significant at the 10% level. Thus, uncertainty about the macroeconomic implications of deflations appears to occur more robustly during or after credit booms, possibly due to concerns of debt deflation, and during periods of demand falling short of supply.

Next, we consider the existence of common global deflationary trends in the behaviour of inflation expectations. Indeed, deflation episodes have often occurred simultaneously across economies (Graph 1), and several studies find an important common component in inflation (eg Ciccarelli and Mojon (2010); Mumtaz and Surico (2012)). To do this, we plot in Graph 5 the estimated time fixed effects from the level regression (Column (3) of Table 1) as the orange line, as well as from the regression for forecast disagreement (Column (2) of Table 2) as the blue line.

Global trends in inflation expectations | Graph 5



Notes: The graph shows the estimated time fixed effect from the dispersion regression as the blue line (left-hand scale; based on Column (2) in Table 2), and from the level regression as the orange line (right-hand scale; based on Column (3) in Table 1).

Source: Authors' calculations.

Graph 5 shows that the time fixed effect from the level regression declined notably over the sample. It dips during the Asian financial crisis and then again during the "deflation scare" of the early 2000s. Another drop occurs during the GFC and then a more modest decline in 2014–15 when many economies are simultaneously experiencing deflations. Thus, there appears to be a global deflationary tendency in expectations during parts of the sample. Moreover, the time fixed effects from the level and disagreement regressions are negatively correlated during some time periods when many countries are experiencing very low inflation or deflation. In particular, the fixed effect from the disagreement regression surges as the fixed effect from the levels regression drops, both in the late 1990s and during the GFC.

Further robustness tests

Table 8

Variable	Level regression		Disagreement regression	
	All deflations	Persistent deflations	All deflations	Persistent deflations
Using a one-sided output gap				
$y_{c,t-1}^{gap}$	0.00224 (0.0154)	0.00324 (0.0150)	–0.0346*** (0.00799)	–0.0341*** (0.00822)
$D_{c,t-1}^{defl}$	–0.149* (0.0759)	–0.302*** (0.0690)	0.155*** (0.0571)	0.154** (0.0667)
$D_{c,t-1}^{defl}\pi_{c,t-1}$	0.161* (0.0918)	0.0878 (0.0595)		
Obs	125,107	125,107	8,061	8,061
R-squared	0.835	0.835	0.578	0.575
Using a shadow interest rate				
$i_{c,t-1}$	–0.00597 (0.00414)	–0.00645 (0.00421)	–0.00323** (0.00135)	–0.00328** (0.00130)
$(\Delta i_{c,t-1})^2$			1.28e–05*** (2.11e–06)	1.31e–05*** (2.08e–06)
$D_{c,t-1}^{defl}$	–0.146* (0.0761)	–0.301*** (0.0672)	0.135** (0.0596)	0.138* (0.0712)
$D_{c,t-1}^{defl}\pi_{c,t-1}$	0.156* (0.0916)	0.0842 (0.0572)		
Obs	125,107	125,107	8,061	8,061
R-squared	0.837	0.837	0.570	0.568

Notes: The models for level regressions are based on the specifications of Columns 3 and 5 in Table 1; those for disagreement regressions are based on the specifications of Columns 2 and 3 in Table 2. Robust standard errors clustered by forecaster and time (country and time in Columns 3 and 4) in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. All models include forecaster and time fixed effects (country and time fixed effects in Columns 3 and 4).

We also estimate the models using alternative measures for two of the explanatory variables. First, instead of using a two-sided filter to construct the output gap, we consider a one-sided HP filter so that information about future output is not used to compute the trend at any point in time. Second, given that policy rates have been at or near zero during parts of the estimation sample, we use shadow rates constructed by Krippner (2016) based on an affine term structure model.[25] These capture the effect of unconventional monetary policy measures on the monetary policy stance, and they are available for the United States, euro area, Japan and the United Kingdom, from 1995 onwards. For countries in the euro area, we use the euro area shadow rate for the time period during which the country has been part of the single currency area. Table 8 shows the coefficient estimates both for the alternative

[25] The underlying data and methodology are available at: https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures (accessed 5 December 2017).

variables themselves, as well as for the deflation dummy variables. Our main results appear broadly robust to these alternative measures, although the output gap loses its significance in the level regressions when the one-sided measure is used.

6. Conclusion

In this paper, we analyse the behaviour of inflation expectations during periods of deflation, using a large cross-country data set of Consensus forecasts. We find some evidence of an unanchoring of expectations. Deflations are associated with a downward shift in the level of inflation expectations, somewhat higher backward-lookingness and greater forecast disagreement.

Whereas previous research has documented that forecast disagreement is increasing in the level of actual inflation outcomes, we uncover a U-shaped relationship when deflations are included, such that forecast disagreement rises with the absolute levels of both inflation and deflation outcomes. The increase in disagreement occurs over and above that caused by low positive inflation rates or deviations of inflation from the central bank's target. Our data suggest that the magnitude of forecast disagreement at an inflation rate of –1.7%, the lowest inflation outcome on average during deflation episodes, is similar to that observed when inflation rates are around 6%.

Delving deeper into the forecast distribution, we find that deflations are associated with movements in the left-hand tail rather than in the right-hand one. Such shifts appear to have macroeconomic implications: in addition to temporarily affecting output and inflation outcomes, negative shocks to the lower tail of inflation forecasts also lead to stronger disagreement about output forecasts.

While the paper provides the first systematic attempt to analyse forecast behaviour during deflation periods in a large number of economies, it leaves a number of questions open. For instance, it would be interesting to analyse which theoretical model could describe the behaviour of inflation expectations during deflations. While the dynamics of forecast disagreement appear to be partly consistent with sticky information model or rational inattention models, there are questions as to what extent such frameworks can be used to describe the behaviour of professional forecasters during deflations. Relatedly, one may wish to explore how forecast disagreement changes over time as the economy moves through deflation and eventually escapes from it. Finally, the costs of inflation forecast disagreement deserve further study, potentially by conducting a systematic analysis of the relationship between forecast dispersion and a large number of macroeconomic indicators.

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Data coverage

Annex Table A1

Economy	Start	End	Number of months	No of forecasters			Total observations
				Minimum	Maximum	Average	
Argentina	Apr.01	Apr.16	181	7	25	15.1	2734
Bulgaria	May.07	Jun.16	110	8	16	11.9	1309
Brazil	Apr.01	Jun.16	183	13	27	18.0	3303
Canada	Jan.90	Jun.16	318	11	20	15.2	4847
Switzerland	Jun.98	Jul.16	218	6	17	13.3	2891
Chile	Apr.01	Jul.16	184	11	23	17.0	3122
China	Dec.94	Jun.16	259	11	24	17.9	4624
Colombia	Apr.01	Jul.16	184	7	16	12.2	2251
Czech Republic	May.07	Jun.16	110	13	22	17.0	1869
Germany	Jan.90	Jul.16	319	12	32	26.5	8457
Estonia	May.07	Jul.16	111	6	12	9.2	1023
Spain	Jan.95	Jul.16	259	7	19	13.9	3607
France	Jan.90	Jul.16	319	6	26	17.8	5692
United Kingdom (CPI)	Jan.05	Jun.16	138	19	29	24.5	3382
United Kingdom (RPI)	Jan.90	Dec.04	180	18	39	29.5	5308
Hong Kong SAR	Dec.94	Jun.16	259	9	21	15.4	3984
Croatia	May.07	Jun.16	110	7	17	11.3	1238
Hungary	May.07	Jun.16	110	12	25	16.5	1810
Indonesia	Dec.94	Jul.16	260	7	20	13.9	3601
India	Dec.94	Jun.16	259	5	19	10.9	2823
Italy	Jan.90	Jul.16	319	6	21	13.8	4406
Japan	Jan.90	Jun.16	318	5	25	17.2	5481
Korea	Dec.94	Jul.16	260	9	22	15.2	3949
Lithuania	May.07	Jun.16	110	6	12	8.0	883
Latvia	May.07	Jun.16	110	7	14	9.5	1043
Mexico	Apr.01	Jul.16	184	9	27	19.3	3549
Malaysia	Dec.94	Jun.16	259	10	23	15.1	3916
Netherlands	Jan.95	Jul.16	259	7	14	9.4	2430
Norway	Jun.98	Jun.16	217	5	12	9.2	2007
Peru	Apr.01	Jul.16	184	7	17	11.8	2177
Philippines[1]	Dec.94	Jul.16	260	12	21	15.4	1526
Poland	May.07	Jun.16	110	12	25	17.3	1901
Romania	May.07	Jul.16	111	7	19	12.4	1374
Russia	May.07	Jul.16	111	10	24	16.3	1807
Sweden	Jan.95	Jun.16	258	6	18	13.4	3470
Singapore	Dec.94	Jun.16	259	8	19	14.7	3800
Slovenia	May.07	Jul.16	111	7	16	10.6	1179
Slovakia	May.07	Jun.16	110	8	15	11.4	1249
Thailand	Dec.94	Jul.16	260	8	22	13.9	3623
Turkey	May.07	Jul.16	111	9	21	15.2	1683
Chinese Taipei	Dec.94	Jul.16	260	9	22	14.3	3720
Ukraine	May.07	Jul.16	111	8	19	14.4	1599
United States	Jan.90	Jun.16	318	16	33	25.8	8203
Venezuela	Apr.01	Dec.15	177	7	19	13.6	2402

Deflation episodes[1]

Annex Table A2

Economy	Start	End	Length (months)	Minimum current year forecast	Minimum next year forecast	Minimum inflation outcome
Argentina	Jun.01	Feb.02	9	–1.6	–0.9	–1.7
Chile	Aug.09	Mar.10	8	–1.3	2.7	–2.3
Bulgaria	Aug.13	Apr.15	21	–1.3	1.1	–2.6
Estonia	May.09	Apr.10	12	–0.8	–0.2	–2.2
Estonia	Jun.14	Jul.16	26	–0.4	1.3	–1.3
Croatia	Feb.14	Jun.16	29	–0.7	1.0	–1.9
Hungary	Sep.14	Jun.15	10	–0.1	1.5	–1.4
Lithuania	Dec.14	Feb.16	15	–0.7	1.4	–1.8
Latvia	Oct.09	Oct.10	13	–3.0	–3.1	–4.2
Latvia	Jan.16	Jun.16	6	–0.1	1.7	–0.8
Poland	Aug.14	Jun.16	23	–0.9	0.7	–1.3
Romania	Jun.15	Jul.16	14	–1.2	–0.2	–3.5
Slovenia	Jan.15	Jul.16	19	–0.5	0.8	–0.8
Slovakia	Feb.14	Jun.16	29	–0.3	0.9	–0.8
Ukraine	Nov.12	Dec.13	14	–0.3	3.3	–0.8
Switzerland	Mar.09	Dec.09	10	–0.5	0.6	–1.2
Switzerland	Oct.11	Dec.13	27	–0.6	–0.1	–1.1
Switzerland	Sep.14	Jul.16	23	–1.3	–0.3	–1.4
Spain	Mar.09	Dec.09	10	–0.3	1.3	–1.4
Spain	Jul.14	Jul.16	25	–1.1	0.5	–1.3
France	May.09	Dec.09	8	0.1	1.1	–0.7
Italy	Feb.16	Jul.16	6	–0.1	0.9	–0.5
Japan	Oct.95	May.96	8	0.0	0.2	–0.7
Japan	Feb.99	Oct.04	69	–1.0	–0.9	–1.6
Japan	Jun.05	Jun.06	13	–0.2	0.1	–1.0
Japan	Feb.09	Aug.11	31	–1.3	–1.0	–2.5
Japan	Jun.12	Jul.13	14	–0.2	–0.1	–0.9
Sweden	Sep.96	Jun.97	10	0.8	1.3	–0.4
Sweden	Jun.98	Apr.99	11	0.3	0.6	–1.2
Sweden	Apr.09	Jan.10	10	–0.4	0.8	–1.9
Sweden	Aug.14	Oct.15	15	–0.2	0.7	–0.4
United States	Mar.09	Dec.09	10	–1.0	1.6	–2.1
China	Apr.98	Jun.00	27	–1.3	1.2	–2.2
China	Mar.02	Feb.03	12	–0.8	0.3	–1.3
China	Feb.09	Dec.09	11	–0.7	1.4	–1.8
Hong Kong SAR	Nov.98	Aug.04	70	–3.6	–1.5	–6.1
Malaysia	Jun.09	Jan.10	8	0.6	2.0	–2.5
Singapore	Jun.98	Jun.99	13	–0.6	–0.5	–1.5
Singapore	Nov.01	Dec.02	14	–0.4	1.1	–1.1
Singapore	Jun.09	Feb.10	9	–0.2	1.4	–0.9
Singapore	Nov.14	Jun.16	20	–0.5	0.5	–1.6
Thailand	May.99	Dec.99	8	0.3	2.2	–1.2
Thailand	Jan.09	Nov.09	11	–1.0	2.1	–4.4
Thailand	Jan.15	Jun.16	18	–0.8	1.4	–1.3

Deflation episodes[1]

Annex Table A2 (cont.)

Economy	Start	End	Length (months)	Minimum current year forecast	Minimum next year forecast	Minimum inflation outcome
Chinese Taipei	Jun.03	Feb.04	9	–0.3	0.5	–1.0
Chinese Taipei	Feb.09	Feb.10	13	–1.2	0.7	–2.3
Chinese Taipei	Jan.15	Oct.15	10	–0.4	1.1	–0.9

[1] See the definition of deflation episodes in Graph 1. The length of deflation episodes in this table includes the two consecutive months of positive inflation rates that potentially follow deflation. The minimum forecast refers to the lowest median forecast across forecasters.

Sources: Consensus; National data; authors' calculations.

Data sources

Annex Table A3

Variable	Source	Data transformations
CPI inflation	National data	
Inflation expectations	Consensus Economics	
GDP growth expectations	Consensus Economics	
Nominal effective exchange rate	National data	
Output gap	IMF, *World Economic Outlook*; national data; authors' calculations	The output gap is calculated as the difference between actual and potential GDP, with the potential GDP estimated using a Hodrick-Prescott-Filter and a smoothing parameter of 1,600 for quarterly data. The data are then converted to monthly frequency by linear interpolation.
Policy interest rate	Datastream; national data	Where policy rates are not available, money market interest rates are used.
Credit gap	National data; BIS	
Shadow interest rate	Krippner (2016)	

Level of inflation expectations, excluding GFC

Annex Table A4

Variable	(1)	(2)	(3)	(4)	(5)
$\pi_{c,t-1}$	0.329*** (0.0163)	0.299*** (0.0163)	0.252*** (0.0147)	0.303*** (0.0166)	0.279*** (0.0166)
$D^{defl}_{c,\,t-1}$		–0.229*** (0.0488)	–0.175** (0.0833)		
$D^{defl}_{c,\,t-1}\pi_{c,t-1}$			0.207** (0.102)		
$D^{High\,infl}_{c,\,t-1}$		0.141*** (0.0403)	–0.158 (0.111)	0.137*** (0.0405)	–0.0817 (0.119)
$D^{High\,infl}_{c,\,t-1}\pi_{c,t-1}$			0.0772*** (0.0237)		0.0527** (0.0256)
$y^{gap}_{c,t-1}$	0.0356*** (0.0137)	0.0354*** (0.0136)	0.0361*** (0.0136)	0.0363*** (0.0136)	0.0373*** (0.0138)
$\Delta neer_{c,t-1}$	–5.355* (3.236)	–5.424* (3.241)	–5.232* (3.004)	–5.350* (3.224)	–5.361 (3.250)
$i_{c,t-1}$	–0.00590 (0.00446)	–0.00572 (0.00453)	–0.00535 (0.00452)	–0.00594 (0.00454)	–0.00603 (0.00450)
$D^{defl\,long}_{c,\,t-1}$				–0.272*** (0.0569)	–0.268*** (0.0682)
$D^{defl\,long}_{c,\,t-1}\pi_{c,t-1}$					0.0525 (0.0618)
Obs	116,209	116,209	116,209	116,209	116,209
R-squared	0.843	0.844	0.845	0.844	0.844

Notes: Dependent variable is the expectation by an individual forecaster for inflation in the next calendar year. Robust standard errors clustered by forecaster and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (2) and (3) show results when the deflation dummy comprises all deflations; columns (4) and (5) include only persistent deflations. All models include forecaster and time fixed effects.

Forecast disagreement, excluding GFC

Annex Table A5

Variable	(1)	(2)	(3)	(4)	(5)
$E_{c,t}(abs(\pi_{c,t+h}))$	0.106**	0.111**	0.106**	0.205***	0.198***
	(0.0440)	(0.0449)	(0.0435)	(0.0724)	(0.0704)
$D^{defl}_{c,t-1}$	0.177**	0.162**		0.268**	
	(0.0665)	(0.0654)		(0.108)	
$D^{High\ infl}_{c,t-1}$	–0.00943	–0.0301	–0.0357	–0.0149	–0.0237
	(0.0541)	(0.0539)	(0.0559)	(0.0829)	(0.0855)
$infl\ gap_{c,t-1}$		0.0442**	0.0497**	0.0796***	0.0887***
		(0.0204)	(0.0209)	(0.0283)	(0.0289)
$(infl\ gap_{c,t-1})^2$		–0.000702	–0.000962	–0.00123	–0.00166
		(0.00145)	(0.00148)	(0.00164)	(0.00169)
$y^{gap}_{c,t-1}$	–0.0358***	–0.0349***	–0.0352***	–0.0697***	–0.0700***
	(0.0118)	(0.0111)	(0.0111)	(0.0186)	(0.0186)
$abs(\Delta\pi_{c,t-1})$	0.0431*	0.0302	0.0282	0.0640	0.0610
	(0.0240)	(0.0248)	(0.0254)	(0.0467)	(0.0481)
$(\Delta\pi_{c,t-1})^2$	0.00534	0.00375	0.00368	0.00239	0.00225
	(0.00821)	(0.00710)	(0.00716)	(0.0118)	(0.0119)
$abs(\Delta neer_{c,t-1})$	6.674***	6.341***	6.400**	10.23***	10.33***
	(2.264)	(2.306)	(2.377)	(3.410)	(3.514)
$i_{c,t-1}$	–0.00258	–0.00297*	–0.00295*	–0.00352	–0.00350
	(0.00181)	(0.00154)	(0.00149)	(0.00331)	(0.00320)
$(\Delta i_{c,t-1})^2$	1.32e–05***	1.25e–05***	1.28e–05***	2.01e–05***	2.06e–05***
	(2.42e–06)	(2.35e–06)	(2.35e–06)	(4.33e–06)	(4.32e–06)
$D^{defl\ long}_{c,t-1}$			0.147**		0.267*
			(0.0707)		(0.140)
Obs	7,414	7,414	7,414	7,414	7,414
R-squared	0.572	0.581	0.578	0.631	0.629

Notes: Dependent variable is the interquartile range of expected inflation for the next calendar year (Columns (1) to (3)) or the interdecile range (Columns (4) and (5)). Robust standard errors clustered by country and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (1), (2) and (4) show results with deflation dummies that comprise all deflations; Columns (3) and (5) include only persistent deflations. All models include country and time fixed effects.

Tails of forecast distribution and deflation

Annex Table A6

Variable	25th pc	25th pc	25th pc	25th pc	75th pc	75th pc	75th pc	75th pc
$\pi_{c,t-1}$	0.294***	0.251***	0.296***	0.265***	0.322***	0.254***	0.318***	0.268***
	(0.0406)	(0.0362)	(0.0380)	(0.0364)	(0.0399)	(0.0359)	(0.0366)	(0.0351)
$D^{defl}_{c,t-1}$	–0.167	–0.145			–0.0334	–0.0469		
	(0.104)	(0.108)			(0.107)	(0.130)		
$D^{High\,infl}_{c,t-1}$	0.150*	–0.112	0.149*	–0.0679	0.181**	–0.290	0.191**	–0.245
	(0.0779)	(0.205)	(0.0766)	(0.211)	(0.0863)	(0.217)	(0.0857)	(0.216)
$D^{defl}_{c,t-1}\pi_{c,t-1}$		0.146*				0.172		
		(0.0770)				(0.118)		
$D^{High\,infl}_{c,t-1}\pi_{c,t-1}$		0.0698		0.0563		0.122**		0.108*
		(0.0545)		(0.0555)		(0.0569)		(0.0559)
$y^{gap}_{c,t-1}$	0.0707***	0.0706***	0.0715***	0.0719***	0.0371	0.0372	0.0372	0.0383
	(0.0242)	(0.0237)	(0.0244)	(0.0241)	(0.0276)	(0.0269)	(0.0278)	(0.0273)
$\Delta neer_{c,t-1}$	–2.547	–2.409	–2.465	–2.448	–5.709	–5.566	–5.693	–5.683
	(2.064)	(1.941)	(2.066)	(2.109)	(4.244)	(4.068)	(4.263)	(4.349)
$i_{c,t-1}$	–0.00913**	–0.00885**	–0.00933**	–0.00933**	–0.00572	–0.00539	–0.00573	–0.00585
	(0.00371)	(0.00371)	(0.00376)	(0.00387)	(0.00522)	(0.00510)	(0.00526)	(0.00524)
$D^{defl\,long}_{c,t-1}$			–0.249*	–0.131			–0.146	–0.138
			(0.134)	(0.108)			(0.131)	(0.106)
$D^{defl\,long}_{c,t-1}\pi_{c,t-1}$				0.176***				0.110
				(0.0647)				(0.0656)
Obs	8,093	8,093	8,093	8,093	8,093	8,093	8,093	8,093
R-squared	0.856	0.857	0.856	0.857	0.857	0.858	0.857	0.858

Notes: Dependent variable is the 25th percentile (Columns (1) to (4)) or the 75th percentile of the forecast distribution (Columns (5) to (8)). Robust standard errors clustered by country and time in parentheses. *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively. Columns (1), (2), (5) and (6) show results from estimations with all deflations; Columns (3), (4), (7) and (8) include only persistent deflations. All models include country and time fixed effects.

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