INFLATION ZONE TARGETING AND SKEWED INFLATION EXPECTATIONS

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April 15, 2013
First Draft: October 14, 2012

Abstract

We study the implications of inflation target zones for the cross-sectional skewness of the distribution of professional economists’ forecasts of inflation rates in the G7 countries. Drawing on a simple continuous-time macro model, we argue that the imposition of an inflation target zone should result in a negative correlation between skewness and inflation rates. We use a Panel Smooth Transition (PSTR) model to test this implication of our model. According to our results, inflation affects skewness negatively within an inflation target zone, and positively outside the boundaries of the inflation target zone. While we also we document cross-country differences, in general, our results suggest that professional forecasters believe that central banks conduct monetary policy via inflation target zones.

Keywords: Inflation target zone; Forecasts; Skewness; Panel Smooth Transition model

JEL Classification: E31, E42, E52

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1 INTRODUCTION

Publishing inflation targets has become increasingly popular among central banks over the last two decades. While some central banks have announced point targets for the inflation rate, most central banks have either explicitly or implicitly specified some form of inflation zone around the inflation target. According to Orphanides and Wieland (2000), an inflation zone may reflect that central bankers have a zone-quadratic objective function, where deviations of the inflation rate from the inflation target receive a quadratic weight outside the inflation zone, and a loss that is almost zero within the inflation zone. As an alternative scenario, they consider a nonlinear Phillips Curve according to which large fluctuations in the inflation rate only result from large positive or negative output gaps. While Orphanides and Wieland (2000) focus on reasons for why central banks may adopt an inflation zone, Gerlach (1994) shows that a credible inflation target stabilizes inflation expectations in much the same way as an exchange-rate target zone stabilizes exchange-rate expectations in Krugman (1991)'s canonical model of exchange rate target zones. More recent research by Levin et al. (2004) shows that a credible inflation target reduces the persistence of inflation and leads to a decoupling of long-run inflation expectations from inflation dynamics. In a similar vein, Demertzis et al. (2009) report that, in the long run, inflation targets anchor inflation expectations.\(^1\) Johnson (2002), in turn, finds that inflation targeting implies that forecasters expect lower inflation rates. Moreover, he shows that announcing an inflation target does not affect the cross-sectional dispersion of forecasts. The cross-sectional dispersion of inflation forecasts summarizes the range of forecasts or, depending on the definition being used, the cross-sectional variance of forecasts. Cecchetti and Hakkio (2010) do not find evidence that inflation targeting lowers the dispersion of professional economists’ inflation forecasts. Capistrán and Ramos-Francia (2010), in contrast, report evidence that the cross-sectional dispersion of inflation forecasts tends to be smaller in inflation targeting countries than in countries that have not officially adopted an inflation target. Dovern et al. (2012) report results in a similar vein. Siklos (2012) shows that central bank transparency on forecast dispersion appears to be ambiguous, and that inflation targets seem to have no or even a positive affect on various measures of forecast dispersion. The ambiguous empirical evidence on the link between inflation targets and the cross-sectional dispersion of forecasts mirrors insights derived in the theoretical literature. For example, Walsh (2007) emphasizes that the optimal degree of central bank transparency depends on the relative importance of demand and supply shocks and their persistence.

Since the sign of the effect of central bank transparency and, thus, inflation targets on the cross-sectional dispersion of forecasts is ambiguous, it is the aim of this paper to analyze the link between the cross-sectional skewness of the distribution of inflation forecasts and the dynamics of the inflation rate. Following Gerlach (1994), we use a simple continuous-time macro model to argue that the implementation of a credible inflation zone around an inflation target should result in a negative correlation between the inflation rate and the skewness of the cross-sectional distribution of inflation forecasts. Our approach to measure skewness from the cross-sectional heterogeneity of survey forecasts is similar to the approach studied by Pierdzioch and Stadtmann (forthcoming), who use the cross-sectional heterogeneity charac-

\(^1\)However, Van der Cruijsen and Demertzis (2011) report weaker evidence for EMU member countries.
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teristic of survey data of exchange rate forecasts to construct various skewness measures. They employ their skewness measures to study the correlation between skewness of the distribution of heterogeneous exchange-rate forecasts with exchange rate movements. Earlier research on the link between skewness and exchange-rate movements includes the research by Campa et al. (1998), who use option data to extract the distribution of expected exchange rate movements. They then correlate the skewness of this distribution with exchange-rate movements. The correlation should be negative because a credible target zone should give rise to stabilizing expectations of central bank interventions. We use a similar theory to motivate our empirical research, but we apply the theory to study inflation forecasts, and we use advanced methods of nonlinear panel econometrics to examine the link between the skewness of the distribution of inflation forecasts and the inflation rate. Specifically, we use the Panel Smooth Transition Regression (PSTR) model which is particularly suited for the nonlinear problem that we study: as we will show, the “honeymoon effect” implies that the link between skewness and the inflation rate should strengthen as the inflation rate approaches the boundaries of the inflation zone.

Using methods of panel econometrics is warranted to fully account for the time-series and the cross-country dimension of the survey data of inflation forecasts that we examine in our empirical analysis. A recent application of a PSTR model to the study of monetary policy based on survey data is the research by Kadilli and Markov (2012). They use survey data to construct measures of central bank credibility and then use a PSTR model to trace out the economic determinants of their credibility measures.

Our work can also be linked to recent research on measuring inflation risk, where the use of the skewness of survey data on inflation expectations leads to promising results. For example, comparing the point estimate and the first moments of the underlying subjective probability distributions for future inflation given in the European Survey of Professional Forecasters (SPF), García and Manzanares (2007a) report considerable differences between the two measures. They suggest that this result is due to the fact that the underlying probability distributions of survey participants are skewed. García and Manzanares (2007b) measure skewness in terms of the asymmetry in the probability forecasts of the U.S. Survey of Professional Forecasters. They show, using data for the Volcker disinflation and the 1980s, that skewness may be a useful measure of central bank credibility and inflation risk. Furthermore, they find that, while inflation skewness seems to be linked to macroeconomic activity, the correlation between inflation skewness and the actual inflation rate is not very strong. They do not account, however, for the kind of nonlinearity in the link between inflation skewness and the actual inflation rate implied by our theoretical model. García and Werner (2010), in turn, use data from the European SPF to analyze the link between inflation risk and inflation risk premia that can be backed out of financial instruments. Again, they do not analyze the nonlinearity in the link between inflation skewness and the actual inflation rate that is the focus of our empirical analysis. In addition, they only study data for the U.S. and the Euro Area, whereas we have assembled data for the G7 countries, implying that we can fully exploit the cross-country dimension of our data by applying methods of panel econometrics to recover the link.

2It is also worth noting that skewness plays an important role in menu-cost models of adjusting prices. This literature traces back to research by Ball and Mankiw (1995), who have developed a menu-cost model to show that the distribution of relative price changes is positively skewed when the inflation rate increases, and vice versa.
between skewness and actual inflation rates. Most recently, Andrade et al. (2012) show that for both the U.S. and the Euro Area, the skewness of inflation expectations helps predict future inflation and clearly outperforms other forecasting models that do not include the skewness. Furthermore, they also find that the central banks in both countries react to the asymmetry of inflation expectations when deciding on the interest rate targets.

Building on these results, we add to the literature as follows. In Section (2) we lay out a simple theoretical model that implies that inflation should affect the skewness of expectations negatively if professional forecasters think that the central bank operates via an inflation target zone. In Section (3), we describe in detail our data set and the application of the PSTR model to study the nonlinear link between inflation and the skewness of expectations. As we describe in Section (4), our results support the view that professional forecasters indeed believe in inflation target zones. Inside the target zone, inflation affects skewness negatively, whereas the effect is positive outside the target zone. Moreover, our findings are consistent with the view that forecasters have an asymmetric target zone in mind: we find the upper boundary to be about as twice as large as the lower boundary. While we document some differences between countries, our results are robust with respect to restricting our panel to Euro Area countries only, and to estimating our baseline equation separately for each country, though the panel estimates are more stable and appear to be more reliable than the single country results. We present some concluding remarks in Section (5).

2 THEORY AND TESTABLE IMPLICATIONS

In order to illustrate the theoretical foundation of our empirical work, we draw on earlier research on exchange-rate target zones. In his seminal paper on the modeling of exchange-rate target zones, Krugman (1991) shows that a credible exchange-rate target zone should have a stabilizing effect on exchange rates. The stabilizing effect arises because forecasters and rational traders in the foreign-exchange market condition their forecasts and their decisions to buy or to sell foreign currency on the likelihood of monetary policy interventions. As the exchange rate approaches one of the boundaries of the central banks’ target zone, the likelihood of stabilizing interventions is getting larger. In consequence, forecasters and rational traders will form increasingly strong expectations of a future large appreciation (depreciation) at the upper (lower) boundary of the exchange-rate target zone. Expectations that a large appreciation (depreciation) is more likely than a further depreciation (appreciation) will induce purchases (sales) of domestic (foreign) assets, implying that anticipated interventions exert a stabilizing effect on the exchange rate (the so called “honeymoon effect”).

A credible inflation target can give rise to a similar expectations-driven stabilizing effect on the inflation rate. Gerlach (1994) shows that such a stabilization mechanism can be derived in a slightly modified version of Krugman (1991)’s canonical exchange-rate target zone model adapted to the study of inflation targets. In Gerlach (1994)’s model a central bank adopts an inflation target by constraining the

\footnote{Alternative modeling approaches can be found in Orphanides and Wieland (2000) and Capistrán and Ramos-Francia (2010).}
inflation rate to fluctuate within some pre-specified interval around the inflation target.\(^4\) As the inflation rate approaches either the upper or the lower boundary of the interval, the central bank tightens or loosens monetary policy and, thereby, ensures that the inflation rate does not cross the boundaries of the interval. The result is a target zone for the inflation rate which, in turn, triggers the kind of stabilizing “honeymoon effect” first described by Krugman (1991).

**A Simple Model**  The following simple model illustrates how the adoption of an inflation target zone may affect inflation expectations. The model consists of three equations: a forward-looking interest-rate rule, a simple IS curve, and a Phillips curve. The interest-rate rule stipulates that the central bank sets the nominal interest rate as follows:

\[
i(t) = r(t) + \pi(t) + \gamma \frac{\mathbb{E}d\pi(t)}{dt},
\]

where \(\gamma > 0\), \(\pi = \) inflation rate, \(i(t) = \) nominal interest rate, \(r(t) = \) real interest rate, \(t = \) continuous time index, and \(\mathbb{E}\) denotes the rational expectations operator. The IS curve specifies that real output, \(y\), is an inverse function of the real interest rate:

\[
y(t) = \alpha(i(t) - \pi(t)),
\]

where \(\alpha < 0\) denotes the real interest rate sensitivity of output. Finally, a simple Phillips curve describes the link between the inflation rate and the output gap:

\[
\pi(t) = \beta(y(t) - \bar{y}),
\]

where \(\beta > 0\) denotes the slope of the Phillips curve, and \(\bar{y}\) denotes the natural output (assumed to be zero hereafter). Combining the Phillips curve with the IS curve and inserting the result into the interest rate rule yields

\[
\pi(t) = \zeta_1 r(t) - \zeta_2 \frac{\mathbb{E}d\pi(t)}{dt}, \text{ with } \zeta_1 = \alpha \beta \text{ and } \zeta_2 = \alpha \beta \gamma.
\]

We assume that the following stochastic differential equation captures the dynamics of the real interest rate:

\[
dr(t) = \sigma dW(t) + dU(t) - dL(t),
\]

where \(\sigma > 0\), \(dW(t)\) denotes the increment to a standard Wiener process with zero mean and unit variance, and \(dU(t)\) and \(dL(t)\) are regulator processes that the central bank activates whenever the inflation rate reaches the upper (\(\pi_U\)) or lower (\(\pi_L\)) boundary of some inflation zone around the inflation target.\(^5\) The inflation rate, thus, is a function of the regulated real interest rate given in Equation (5). We denote this function by \(g(r)\) and use Ito’s Lemma to compute the expected rate of change of the inflation rate within the boundaries of the inflation target zone. We get \(\frac{\mathbb{E}d\pi(t)}{dt} = \frac{1}{2} \sigma^2 g''(r)\), where primes denote

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\(^4\)Gerlach (1994) discusses various variants of an inflation target zone and then assumes that “... the inflation target constrains the price level within \(x\%\) of the price level” (p. 134).

\(^5\)An alternative modeling strategy would be to assume the type of occasional interventions studied by Lewis (1995).
derivatives. Using this result in Equation (4), we get the following second-order ordinary differential equation:

\[ \frac{1}{2} \zeta^2 \sigma^2 g''(r) + g(r) + \zeta_1 r = 0, \]  

where we have dropped the time index. As it is well-known from the theory of exchange-rate target zones, the solution to this equation is given by

\[ \pi(t) = \zeta_1 r(t) + B_1 \exp(\lambda_1 r(t)) + B_2 \exp(\lambda_2 r(t)), \]  

with eigenvalues \( \lambda_{1,2} = \pm \sqrt{-\frac{2}{\zeta^2 \sigma^2}}. \) Invoking continuity and differentiability ('smooth pasting') of the solution at \( \pi^U \) and \( \pi^L \), yields the boundary conditions \( g(r^U) = \pi^U, g(r^L) = \pi^L, g'(r^U) = g'(r^L) = 0 \), which suffice to pin down \( r^U \) and \( r^L \) and the constants of integration \( B_1 \) and \( B_2 \).

Figure (1) shows the solution of the model. When the central bank does not invoke an inflation target zone (dashed line; or when it invokes an inflation zone that is not credible), the solution of the model is simply given by \( \pi(t) = \zeta_1 r(t) \). As a result, the inflation rate is a linear function of the real interest rate. A higher real interest rate crowds out output demand in the IS curve, implying a lower inflation rate, as described by the Phillips curve. Because we assume a driftless process to capture the dynamics of the real interest rate, the instantaneously expected rate of change of the inflation rate - given by \( \mathbb{E} \frac{d \pi}{dt} = (g'')^2 \sigma^2 \) - is always zero in this case. Without an inflation zone, we have \( g'' = 0 \) and, thus, \( \mathbb{E} \frac{d \pi}{dt} = 0 \).

With a credible inflation target zone in place (solid line), in contrast, households form expectations of a decreasing (increasing) inflation rate as the inflation rate reaches the upper (lower) boundary of the inflation target zone. The resulting "honeymoon effect" implies \( g'' < 0 \) (\( g'' > 0 \)) in the upper (lower) half of the inflation target zone and, thereby, stabilizes the inflation rate around the central bank’s inflation target.
Model Implications  In our simple model, we assume that aggregate expectations can be described by the forecast of one representative household. In the real-world, in contrast, research on survey data of inflation forecasts has shown that cross-sectional dispersion is a characteristic feature of forecasts of future inflation rates (Dovern et al., 2012).\textsuperscript{6} Still, our simple model can be used to trace out the implications of a credible inflation zone on expectations formation. Similar to Gerlach (1994)’s inflation-target-zone model and Krugman (1991)’s canonical exchange-rate target zone models, our framework implies that the instantaneously expected rate of inflation should become negative, $E \frac{d\pi}{dt} < 0$, as the inflation rate moves closer to the upper boundary of the inflation zone. As a result, the distribution of heterogeneous forecasts should become tilted towards lower inflation rates. Hence, as the inflation rate approaches the upper boundary of the inflation target zone, the distribution of heterogeneous inflation forecasts should become negatively skewed because the probability of a lower inflation rate is larger than the probability of a further increase in the inflation rate. As the inflation rate reaches the lower boundary of the inflation target zone, in turn, the instantaneously expected rate of inflation should become positive, $E \frac{d\pi}{dt} > 0$. The distribution of heterogeneous forecasts should become increasingly tilted towards higher inflation rates, implying that the distribution of heterogeneous inflation forecasts should become positively skewed when the inflation rate approaches the lower boundary of the inflation zone. Thus, as the inflation rate moves from the lower boundary of the inflation target zone to the upper boundary, skewness should turn from positive to negative, giving rise to a negative correlation of the skewness of heterogeneous forecasts with the inflation rate.

A negative correlation between the skewness of the distribution of heterogeneous inflation forecasts with the inflation rate should only arise in a credible inflation zone. As witnessed by Figure (1), the correlation should be zero if the central bank does not invoke an inflation target zone or if the inflation target zone is not credible because, in this case, we have $g'' = 0$. One could even imagine a situation in which the correlation turns positive, which could arise, for example, if households expect a “realignment” of the inflation target (see also Campa et al., 1998). In the context of exchange-rate target zones, such realignments have been studied by Bertola and Caballero (1992). In their model, the likelihood of a realignment increases as the exchange rate approaches the upper and the lower boundaries of the target zone. Forecasters’ and rational traders’ exchange rate expectations should encompass realignment risk, implying that expectations of a further depreciation (appreciation) will accelerate at the upper (lower) boundary of the target zone. Realignment risk thus implies that a positive skewness of the distribution of heterogeneous exchange rate expectations will reflect that the probability of a further large depreciation exceeds the probability of a large appreciation at the upper boundary of the exchange-rate target zone. Conversely, skewness will be negative at the lower boundary of the target zone because realignment risk inflates the probability of a further appreciation relative to the probability of a large depreciation. It follows that, in contrast to Krugman (1991)’s model, skewness should be positively correlated with exchange rate movements. With respect to inflation, we conclude that the correlation between the skew-
ness of the distribution of heterogeneous inflation forecasts and the inflation rate should be positive if households anticipate “shifts” of an imperfectly credible inflation target.

Summing up, we can test whether forecasters expect that the central bank is committed to implement an inflation target zone by inspecting the correlation between the skewness of inflation forecasts and the dynamics of the actual inflation rate. First, if forecasters do not believe that the central bank imposes an inflation target zone, no systematic effect from the inflation rate onto the skewness of the distribution of heterogeneous inflation forecasts should arise, and therefore, result in a zero correlation between inflation and the skewness of expectations. Second, in case forecasters expect that the central bank implements an inflation target zone, the inflation rate should affect skewness negatively, whereas we should get a positive effect if forecasters expect that the central bank shifts its inflation target.

Note that our model only suggests that the effect from inflation on the skewness of inflation expectations should be strongest if inflation reaches the boundaries of the inflation target zone. If inflation goes further beyond the upper or lower target, the effects can be ambiguous. One scenario could be that forecasters continue to form heterogeneous forecasts of the inflation rate. If so, some forecasters may revise their inflation expectations further away from the inflation target, while others may keep believing that the inflation rate will revert to the inflation target zone in the future. Hence, the absolute magnitude of skewness should decrease. By contrast, an alternative scenario is that forecasters start agreeing more on the future inflation rate if the inflation rate goes beyond the boundaries of the inflation target, resembling the outcome of a model without an inflation zone. This case resembles the near-rational Phillips Curve of Akerlof et al. (2000), where economic agents strongly agree on future inflation in periods of low inflation, start to disagree if prices rise, before again sharing a common belief if prices increase even further. Both scenarios are consistent, however, with the our model’s implication that the effects from inflation on the skewness of expectations should be strongest if inflation approaches the boundaries of the target zone. In our empirical analysis, we apply the Panel Smooth Transition Model for a group of G7 countries in order to test which of these scenarios is consistent with the data.

3 DATA AND ESTIMATION STRATEGY

The Data We use survey data for inflation expectations collected in the G7 countries, i.e., France, Germany, Italy, Canada, Japan, UK, and US. The data set stems from Consensus Economics, a private survey organization based in London. Each month, professional forecasters in private firms and public institutes are asked to provide a forecast for a number of economic variables in different countries, including inflation. Originally, the survey consists of fixed event forecasts which we transform into fixed horizon, i.e. one-year-ahead predictions following the approach in Dovern et al. (2012). These authors also report that on average, about 14 to 18 professional forecasters participate in the survey in Canada, France, Italy and Japan, while in Germany, UK, and the US, the numbers range from 27 to 31. Moreover, they find

http://www.consensus economics.com/
that the number of participants does not vary in any systematic way, and that individuals take part in the survey for at least half of the sample. Regarding the time span, our data set ranges from September 1991 to July 2011. We use the individual responses of the survey to compute the skewness of the cross sectional distribution of inflation forecasts \( \pi_{i,t}^{exp} \) in each month and for each country \( i \) as

\[
\text{skew}_{t} = \frac{E \left[ \left( \pi_{i,t}^{exp} \right)^{3} \right] - 3 \mu \sigma^{2} - \mu^{3}}{\sigma^{3}},
\]

(8)

where \( \mu \) and \( \sigma \) denote the cross sectional mean and standard deviation, respectively. The skewness measure is then related to trend deviations of the inflation rate, arguing that professional forecasters focus on price changes compared to a long-run trend instead of changes in inflation as such. The trend inflation captures the inflation target of the central bank, that can both be constant or time-varying. For the former, we thus use the average inflation rate over the sample, and for the latter the HP-filter. The deviation of inflation from the trend is then used as explanatory variable testing whether professional forecasters think that central banks act according to a target zone around the inflation target. Finally, as it has been shown by Dovern et al. (2012), professional forecasters might react differently to inflation if the economy is in a recession. Therefore, we include dummy variables that take the value 1 if a country is in a recession and 0 otherwise. The data are compiled by the Economic Cycle Research Institute following the methodology of the NBER.

Figure (2) plots the skewness of inflation expectations together with the inflation rates expressed as deviations from their long-run averages and from the HP-filter for the Euro Area countries, whereas Figure (3) shows the remaining countries. Note that, by looking at the graphs, it seems that demeaned inflation exhibits a trend at the beginning of the sample. While we only present results for the full time span September 1991 - July 2011, we also repeat the regressions beginning the sample in January 1995 instead of September 1991. The results (not shown) confirm our baseline estimations.

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8We also smooth the distribution by applying a kernel density estimation, but the results are virtually unchanged.

9Despite our theoretical reason for using inflation deviations, the associated trend adjustment captures possible unit roots in our panel. We have applied various panel unit root tests that strongly suggest that our time series are stationary. Results are available upon request

10http://www.businesscycle.com/
Figure 2: Euro Area Panel

France - Skewness

France - Inflation

Germany - Skewness

Germany - Inflation

Italy - Skewness

Italy - Inflation

Note: Left Panels: Red line - skewness, black - skewness smoothed by kernel; Right Panel: Red line - HP-filtered inflation, black - inflation computed as deviation from mean. The gray shaded areas denote recession periods identified by the Economic Cycle Research Institute.
Figure 3: G4 Panel

Note: Left Panels: red line - skewness, black - skewness smoothed by kernel; Right Panel: Red line - HP-filtered inflation, black - inflation computed as deviation from mean. The gray shaded areas denote recession periods identified by the Economic Cycle Research Institute.
Empirical Strategy  For our econometric analysis, we use the Panel Smooth Transition (PSTR) model developed by Gonzalez et al. (2005) and Fok et al. (2005). This model has been used to analyze energy demand (Destais et al., 2009), the Feldstein-Horioka-puzzle (Fouquau et al., 2008), the cost efficiency of banks (Shen, 2005), and to account for non-linearities in the effects from public investment (Colletaz and Hurlin, 2006), healthcare expenditure (Chakroun, 2010, Mehrara et al., 2010), financial development (Eggoh, 2010, 2011), and inflation (Ibarra and Trupkin, 2011) on economic growth. In the context of inflation expectations, using the PSTR framework, Dräger et al. (2011) find loss aversion in Euro Area citizens’ inflation perceptions, whereas Kadilli and Markov (2012) model nonlinear effects from inflation on the expectation gap of professional forecasters in the Euro Area.

In the PSTR model, the effects of explanatory variables change in line with the level of a transition variable. If the transition variable exceeds a certain threshold, one receives estimated coefficients different from the ones that correspond to values below the threshold. Furthermore, the model allows a smooth transition between regimes which makes it different from the threshold model of Hansen (1999) which assumes an immediate shift at the threshold. With regard to our research question, the PSTR model yields those inflation rates that, in the view of professional forecasters, constitute the upper and the lower boundary of the central bank’s inflation target zone. Furthermore, fitting the PSTR model reveals how the distributions of professional forecasters’ expectations change if inflation moves from the baseline regime where inflation is in the middle of the target zone to the upper and lower boundary of the target zone: if professional forecasters quickly update their expectations, we get a steep transition function. Finally, the model allows for either two or three regimes. In the first case, we would get a normal regime inside the target zones, and a second regime consisting of positive and negative deviations from the boundaries. Adding a third regime makes it possible to include asymmetries in forecasters’ perceptions of the target zone. If experts consider the upper boundary of the target zone to be larger than the lower boundary, we would receive two different thresholds. However, we cannot allow for different reaction functions in the upper and in the lower regime, since the slope coefficients of the outer regimes are assumed to be equal in the PSTR framework. Expressed formally, we estimate the following equation:

\[
s_{i,t} = \mu_i + \beta_1 s_{i,t-1} + \beta_2 \pi_{i,t}^{cyclic} + \beta_3 \pi_{i,t}^{cyclic} + \left[ \delta_1 s_{i,t-1} + \delta_2 \pi_{i,t}^{cyclic} + \delta_3 \pi_{i,t-1}^{cyclic} \right] G + \epsilon_{i,t} \tag{9}\]

In this equation, the \(\mu_i\)’s denote country-specific fixed effects, the coefficients \(\beta_j\) give the effects that occur if inflation is within the target zone, whereas the \(\delta_j\)’s indicate the reaction of professional forecasters if inflation is beyond the boundaries. In the case of three regimes, which applies if the lower boundary differs from the upper boundary, the \(\delta_j\)’s capture the common effects in both regimes, i.e. \(\delta_{regime1} = \delta_{regime2} = \delta\). Lastly, the function \(G\) models the transition from one regime to the other. Using the logistic function, \(G\) is given by

\[
G(q_{i,t}; \gamma, c) = \left(1 + exp\left(-\gamma G \prod_{k=1}^{m} (q_{i,t} - c_k)\right)\right)^{-1}, \tag{10}\]
Hence, $G$ depends on three parameters. First, $q_{i,t}$ is the transition variable that leads to a nonlinear relationship between the explanatory variables and the dependent variable. In our model, we use the deviation of inflation from its trend, $\pi_{i,t}^{cyclic}$, as transition variable: if inflation rises up to a certain level, further price changes will affect the distribution of expectations more (or less) strongly. Second, $\gamma$ models the steepness of the transition function: if $\gamma$ is large, professional forecasters switch immediately to the new regime if inflation reaches the boundaries of the target zone, whereas the transition occurs gradually for low values of $\gamma$. Third, the $c_j$'s are the threshold parameters, i.e. those values of the inflation rate considered as the target zone by professional forecasters. As outlined before, the PSTR model permits us to estimate one or two threshold parameters, leading to a model with two or three regimes. A priori, there is no reason to assume that central banks try to implement a symmetric target zone. For example, the European Central Bank (ECB) defines price stability as “inflation of below, but close to 2%”. Hence, we will estimate a model allowing for two different threshold parameters $c_1$ and $c_2$. In this respect, it should be mentioned that we still have to assume that professional forecasters react in the same way to changes of inflation no matter if those go beyond the upper or the lower boundaries of the target zone.

In total, we estimate 8 different models. Model M1 is the version stated in equation (9), whereas in a second model, we add the recession dummy variable in the linear part. In models M3 and M4, we use inflation expressed as deviations from the mean, instead of HP-filtered inflation employed in M1 and M2. Finally, we reestimate models M1-M4 dropping the lagged skewness from the nonlinear part, thereby modifying equation (9) as:

$$skew_{i,t} = \alpha_1 x'_{i,t} + \theta_1 x'_{i,t} q_{i,t} + \theta_2 x'_{i,t} q_{i,t}^2 + \ldots + \theta_m x'_{i,t} q_{i,t}^m + u_{i,t}$$ (12)

Before estimating the model\textsuperscript{11}, we test for the existence of nonlinearity. Since the PSTR model in equation (9) collapses to a linear fixed effects model if $\gamma = 0$, one could test $H_0 : \gamma = 0$ vs. $H_1 : \gamma \neq 0$. However, as it is shown by Hansen (1996), this test would be non-standard given that the model contains unidentified parameters under the null hypothesis. This problem is solved by replacing the function $G$ in equation (9) by the first-order Taylor expansion around $\gamma = 0$, obtaining

$$skew_{i,t} = \mu_i + \beta_1 skew_{i,t-1} + \beta_2 \pi_{i,t}^{cyclic} + \beta_3 \pi_{i,t-1}^{cyclic} + \left[ \delta_2 \pi_{i,t}^{cyclic} + \delta_3 \pi_{i,t-1}^{cyclic} \right] G + \varepsilon_{i,t}$$ (11)
as suggestive evidence and concentrate more on the other results of the model.

Before turning to the estimation results, it is important to note that until present, it is still unclear how the Panel Smooth Transition model as well as the Panel Threshold model of Hansen (1999) behaves in the case of a lagged endogenous variable. Since we use monthly data, we have no choice but to incorporate the impact of both the past value of skewness and of the inflation rate. Hence, in order to check the reliability of our panel estimation, we also run single country regressions applying the Smooth Transition Regression Model developed by Granger and Teräsvirta (1993)\(^\text{13}\). These single country regressions will also enable us to estimate country-specific values of the threshold and the slope parameter of the transition function.

4 ESTIMATION RESULTS

This section presents the empirical results of our panel and single country regressions. We start with the results of the G7 panel which are summarized in Table (1) on the next page. The first four columns show the estimation results for models M1-M4 including the lagged skewness in the nonlinear part of the PSTR model, whereas the remaining columns report the results for models that use the skewness of the previous period only in the linear part.

To begin with the linearity tests, the results at the bottom of the table suggest that a standard linear fixed effects model suffices to capture the effect from inflation on the skewness of inflation expectations.\(^\text{14}\) Still, given the low power of the tests, it is not surprising that the estimated coefficients shows that the model yields quite reasonable results. For all different specifications, we find highly significant threshold variables, a positive and a negative one. If we use the HP-filter to capture trend inflation, the positive threshold is found to be about twice as large as the negative threshold, while we get the contrary result if we use the average inflation rate. The choice of the best model can be motivated by comparing the residual sum of squares (RSS) and the information criteria. Furthermore, note that those models that do not use the lagged skewness in the nonlinear part are more in line with our theoretical model: while we expect professional forecasters to react to changes in inflation that are close to the boundary of the inflation target zone, there is no reason why this should affect the persistence of inflation forecasts. Thus, based on theoretical arguments and comparing the RSS, the results in Table (1) suggest that the HP-filter yields a better fit than the average inflation rate. Hence, we conclude that professional forecasters indeed seem to have an inflation target zone in mind which is found to be asymmetric: positive deviations from trend inflation yield a kink in the estimated coefficients at 0.55, while the lower boundary stemming from negative deviations is estimated at −0.26. Next, looking at the transition function, we find very large values of $\gamma$ which are significantly different from zero only for model M2. Hence, professional forecasters

\(^{12}\) See also Teräsvirta (1994, 2004).
\(^{13}\) See also Teräsvirta (1994, 2004).
\(^{14}\) We report only the F-version of the test. A LM- and pseudo-LR test are available as well, but lead to the same conclusion.
appear to switch immediately from the “within target zone”-regime to the “out of target zone”-regime, while the failure to reject the null of the t-test might be explained by cross-sectional heterogeneity.

Table 1: Estimation Results - G7 Panel

<table>
<thead>
<tr>
<th>Trend of Dep Var:</th>
<th>Nonlinear</th>
<th>Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>HP</td>
<td>Mean</td>
</tr>
<tr>
<td>( \gamma_G )</td>
<td>M1</td>
<td>M2</td>
</tr>
<tr>
<td>17654.20</td>
<td>5723.77***</td>
<td>1668.64</td>
</tr>
<tr>
<td>(25985.68)</td>
<td>(451.73)</td>
<td>(6380.22)</td>
</tr>
<tr>
<td>( c_{1,G} )</td>
<td>-0.26***</td>
<td>-1.33***</td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>( c_{2,G} )</td>
<td>0.55***</td>
<td>0.83***</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.03)</td>
<td>(0.02)</td>
</tr>
</tbody>
</table>

Table Note: Standard errors below coefficients. ***, **, * denote significance at the 1%, 5%, and 10% level. Time span: 1991m9-2011m7

Finally, we turn to the interpretation of the estimated coefficients, thereby testing whether professional forecasters believe in a credible target zone or whether they anticipate shifts in the inflation target. It turns out that the contemporaneous linear and nonlinear effect of the inflation rate is mostly not significantly different from zero (with the exception of the nonlinear effect in models M7 and M8, which are significantly positive). However, the linear effect from past inflation is significantly negative and the nonlinear effect significantly positive for those models that use price deviations from the the HP-filter.
which provides further evidence for the use of HP-filtered inflation. We also report the sum of the estimated linear and nonlinear effects at the bottom of Table (1), still yielding negative signs for the linear and positive signs for the nonlinear part. Thus, our estimation results give evidence for the model’s implication of a credible target zone. Finally, we do not find a significant effect of the recession dummy.

The PSTR model captures heterogeneity across countries by allowing for time-varying and country-specific coefficients (in addition to cross-country fixed effects). This feature arises from the fact that the coefficients change in line with changes of the transition variable: At each date, the model separates the countries into different classes depending on whether or not their inflation rates are beyond the estimated thresholds. Thus, we can compute time-varying and country-specific marginal effects as:

\[
\frac{\partial \text{skew}_{i,t}}{\partial \pi_{i,t}^{\text{cyclic}}} = \beta_2 + \delta_2 G + \beta_2 \pi_{i,t}^{\text{cyclic}} \frac{\partial G}{\partial \pi_{i,t}^{\text{cyclic}}}
\]  

(13)

and

\[
\frac{\partial \text{skew}_{i,t}}{\partial \pi_{i,t-1}^{\text{cyclic}}} = \beta_3 + \delta_3 G + \beta_3 \pi_{i,t-1}^{\text{cyclic}} \frac{\partial G}{\partial \pi_{i,t-1}^{\text{cyclic}}}
\]  

(14)

The Figures (4) and (5) plot the sum of the contemporaneous and lagged marginal effects of inflation for model M1 using HP-filtered inflation as the transition variable. The first graph shows the marginal effects together with HP-filtered inflation and the second graph compares the marginal effects with the skewness of inflation expectations. Because our transition variable differs across panel units, we get a separate plot for each country. As it turns out, professional forecasters switch relatively often between the two regimes. Moreover, we observe differences between countries. Forecasters in the U.S. and Italy less frequently update their reaction to changes in the inflation rate than their colleagues in other countries. Finally, the model captures the time-variation in forecasters’ expectations rather well. In times when inflation is close to its long-run mean, price changes affect the skewness negatively, whereas in periods when inflation is considered to be beyond the implicit target zones of central banks, the coefficient turns positive.\(^{15}\)

\(^{15}\)We show the same plots for model M3 using demeaned inflation as transition variable in Figures (A.1) and (A.2) in the Appendix. Compared to the baseline plots, professional forecasters are now found to switch less often between the two regimes.
Figure 4: G7 Panel - Marginal Effects (Inflation and HP-Filtered Inflation)

Note: Black line: HP-filtered inflation (left axis). Red line: Sum of marginal effects of contemporaneous and lagged HP-filtered inflation (right axis).
Figure 5: G7 Panel - Marginal Effects (Inflation and Skewness of Inflation Expectations: HP-Filtered Inflation)

Note: Black line: Skewness (left axis). Red line: Sum of marginal effects of contemporaneous and lagged HP-filtered inflation (right axis).
Next, we test whether our results are sensitive to the countries included in our panel. For this purpose, we reestimate the model using only the countries of the Euro Area (France, Germany, and Italy), since we expect this group of countries to be more homogeneous than the larger G7 panel used previously. The results are given in Table (2).

Table 2: Estimation Results - Euro Area Panel

<table>
<thead>
<tr>
<th>Trend Dep Var:</th>
<th>Nonlinear</th>
<th>Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>M1</td>
<td>M2</td>
</tr>
<tr>
<td>( \gamma_G )</td>
<td>15.56</td>
<td>15.42</td>
</tr>
<tr>
<td>(14.52)</td>
<td>(11.98)</td>
<td>(9.10)</td>
</tr>
<tr>
<td>( c_{1,G} )</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>(2.39)</td>
<td>(3.01)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>( c_{2,G} )</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>(2.39)</td>
<td>(3.00)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>skew_{i,t-1}</td>
<td>0.44***</td>
<td>0.44***</td>
</tr>
<tr>
<td>(0.14)</td>
<td>(0.14)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>skew_{i,t-1} G</td>
<td>0.12</td>
<td>0.13</td>
</tr>
<tr>
<td>(0.17)</td>
<td>(0.17)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>( \pi_{cyclic} )</td>
<td>0.81*</td>
<td>0.83*</td>
</tr>
<tr>
<td>(0.49)</td>
<td>(0.49)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>( \pi_{cyclic} ) G</td>
<td>-0.87*</td>
<td>-0.89*</td>
</tr>
<tr>
<td>(0.53)</td>
<td>(0.52)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>( \pi_{cyclic} ) G</td>
<td>-0.91***</td>
<td>-0.91***</td>
</tr>
<tr>
<td>(0.31)</td>
<td>(0.31)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>( \pi_{cyclic} ) G</td>
<td>1.03**</td>
<td>1.02**</td>
</tr>
<tr>
<td>(0.37)</td>
<td>(0.37)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>rec_{i,t}</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>(0.04)</td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>( \sum \pi )</td>
<td>-0.10</td>
<td>-0.08</td>
</tr>
<tr>
<td>( \sum \pi G )</td>
<td>0.16</td>
<td>0.13</td>
</tr>
<tr>
<td>RSS</td>
<td>173.22</td>
<td>173.14</td>
</tr>
<tr>
<td>AIC</td>
<td>-1.395</td>
<td>-1.393</td>
</tr>
<tr>
<td>SC</td>
<td>-1.338</td>
<td>-1.329</td>
</tr>
</tbody>
</table>

Linearity Test: F 0.91 0.91 0.99 0.95 1.34 1.34 1.28 1.23
p-value 0.434 0.434 0.396 0.415 0.262 0.264 0.278 0.293

Note: Standard errors below coefficients. ***, **, * denote significance at the 1%, 5%, and 10% level. Time span: 1991m9-2011m7

Note: Note: Standard errors below coefficients. ***, **, * denote significance at the 1%, 5%, and 10% level. Time span: 1991m9-2011m7
Starting with the linearity tests, we still fail to reject the null hypothesis of a linear fixed effects model but, as in case of the G7 panel, we get quite reasonable estimates. With regard to the fit of the different models, those specifications using HP-filtered inflation now perform worse. The models M1 and M2 that allow for nonlinear effects of the lagged skewness suggest that one threshold might be sufficient, since the estimation comes up with the same values of $c_1$ and $c_2$. Dropping the lagged skewness from the nonlinear part again results in a negative and a positive threshold, but the estimated coefficient of inflation changes its sign: Models M5 and M5 suggest that a rise in current and past inflation affects the skewness of inflation expectations positively, and not negatively as it is the case for the G7 panel. Those models using demeaned inflation, however, replicate our baseline results. Professional forecasters seem to believe in a target zone of which the lower boundary is wider than the upper boundary, and inflation affects the skewness negatively within the target zone, but positively outside its boundaries.

Finally, we present results of single country-by-country Smooth Transition Autoregressive (STAR) models. Until present, the behavior of the PSTR model including lags of the dependent variable is not yet formally explored. We thus check the robustness of our results by presenting single STAR estimates following Granger and Teräsvirta (1993). This exercise also allows us to estimate country-specific thresholds and slopes of the transition function. We present in Table (3) only one model specification for each country, i.e., the one that gives the best fit. The remaining models lead to fairly similar conclusions and are available upon request. Overall, the single country results generally support our previous analysis, but also reveal some differences between countries. The regressions for France and Italy corroborate the results of the panel estimates. Moreover, we also estimate a negative and a positive threshold for Canada and the US, however, in both countries, changes in inflation seems to affect the skewness of expectations positively within the target zone. In the US, and also in the UK, we even get a negative effect from inflation on expectations outside the target zone. Finally, we find two negative thresholds in Germany and Japan, and two positive ones in the UK. Overall, while the single STAR results uncover some differences between countries, the panel model results seem to give a more stable and reliable view on the issue under investigation. Moreover, the country-by-country-results in general do not contradict the impression from the panel analysis. This is confirmed e.g. by the negative result for $\sum \pi$ for France, Germany, Italy and Japan which is in line with our panel results.
Table 3: Estimation Results - Single Countries

<table>
<thead>
<tr>
<th></th>
<th>CN</th>
<th>FR</th>
<th>DE</th>
<th>IT</th>
<th>JP</th>
<th>UK</th>
<th>US</th>
</tr>
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<tr>
<td>$\gamma_G$</td>
<td>50.01</td>
<td>104.56</td>
<td>56.74</td>
<td>37.11</td>
<td>10.00</td>
<td>206.20</td>
<td>19.16</td>
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<td>(253.33)</td>
<td>(7797.44)</td>
<td>(154.31)</td>
<td>(38.69)</td>
<td>(12.49)</td>
<td>(1564.47)</td>
<td>(20.38)</td>
</tr>
<tr>
<td>$c_{1,G}$</td>
<td>-0.81**</td>
<td>-0.88***</td>
<td>-1.14***</td>
<td>-1.40***</td>
<td>-3.02***</td>
<td>0.77***</td>
<td>-0.32*</td>
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<tr>
<td></td>
<td>(0.38)</td>
<td>(0.02)</td>
<td>(0.10)</td>
<td>(0.07)</td>
<td>(0.81)</td>
<td>(0.02)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>$c_{2,G}$</td>
<td>0.84***</td>
<td>2.09</td>
<td>-0.22***</td>
<td>0.43**</td>
<td>-1.81***</td>
<td>6.31</td>
<td>0.76***</td>
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<td></td>
<td>(0.05)</td>
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<td>(0.17)</td>
<td>(0.00)</td>
<td>(12.89)</td>
<td>(0.13)</td>
</tr>
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<td>-0.32***</td>
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<td>-3.91***</td>
<td>0.22</td>
<td>-0.01</td>
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<td>(0.04)</td>
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<td>(0.12)</td>
<td>(0.92)</td>
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</tr>
<tr>
<td>const$G$</td>
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<td>1.26***</td>
<td>0.29***</td>
<td>0.18</td>
<td>3.98***</td>
<td>-0.24*</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.35)</td>
<td>(0.13)</td>
<td>(0.13)</td>
<td>(0.91)</td>
<td>(0.14)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>skew$_{i,t-1}$</td>
<td>0.32***</td>
<td>0.49***</td>
<td>0.52***</td>
<td>0.50***</td>
<td>0.36***</td>
<td>0.69***</td>
<td>0.69***</td>
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<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.04)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>skew$_{i,t-1}G$</td>
<td>0.39***</td>
<td>-0.47*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.30**</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.24)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>0.12</td>
<td>0.83***</td>
<td>0.52</td>
<td>1.10</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td>(0.36)</td>
<td>(0.26)</td>
<td>(0.41)</td>
<td>(0.81)</td>
<td>(0.19)</td>
<td>(0.26)</td>
</tr>
<tr>
<td>$\pi_{cyc,i,t-1}$</td>
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<td>-0.23*</td>
<td>0.18</td>
<td>0.15</td>
<td>-0.36</td>
<td>0.10</td>
<td>0.40**</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
<td>(0.06)</td>
<td>(0.16)</td>
<td>(0.30)</td>
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<td>(0.15)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>$\pi_{cyc,i,t-1}G$</td>
<td>0.16</td>
<td>0.72*</td>
<td>-0.36*</td>
<td>-0.03</td>
<td>0.30</td>
<td>-0.12</td>
<td>-0.55**</td>
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<tr>
<td></td>
<td>(0.14)</td>
<td>(0.37)</td>
<td>(0.20)</td>
<td>(0.38)</td>
<td>(0.55)</td>
<td>(0.17)</td>
<td>(0.22)</td>
</tr>
<tr>
<td>rec$_{i,t}$</td>
<td>0.15*</td>
<td>-</td>
<td>0.18*</td>
<td>-0.14*</td>
<td>-</td>
<td>0.08</td>
<td></td>
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<tr>
<td></td>
<td>(0.09)</td>
<td>-</td>
<td>(0.10)</td>
<td>(0.07)</td>
<td>-</td>
<td>(0.08)</td>
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</tr>
<tr>
<td>$\sum \pi$</td>
<td>0.02</td>
<td>-0.06</td>
<td>-0.39</td>
<td>-0.35</td>
<td>-1.38</td>
<td>0.02</td>
<td>0.34</td>
</tr>
<tr>
<td>$\sum \pi G$</td>
<td>0.02</td>
<td>0.84</td>
<td>0.47</td>
<td>0.49</td>
<td>1.40</td>
<td>-0.07</td>
<td>-0.40</td>
</tr>
<tr>
<td>AIC</td>
<td>-1.423</td>
<td>-1.430</td>
<td>-1.643</td>
<td>-1.158</td>
<td>-1.230</td>
<td>-1.711</td>
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<td>-0.998</td>
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<td>-1.565</td>
<td>-1.448</td>
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<td>HQ</td>
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<td>-1.365</td>
<td>-1.584</td>
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<td>$R^2$adj</td>
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<td>0.350</td>
<td>0.361</td>
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<td>0.611</td>
<td>0.444</td>
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<th>Mean</th>
<th>HP</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
<th>HP</th>
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<tbody>
<tr>
<td>Linearity Test: F</td>
<td>p-value</td>
<td>0.446</td>
<td>0.204</td>
<td>0.556</td>
<td>0.545</td>
<td>0.703</td>
<td>0.709</td>
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</table>

Note: Standard errors below coefficients. ***, **, * denote significance at the 1%, 5%, and 10% level. Time span: 1991m9-2011m7
5 CONCLUSION

We have analyzed the link between inflation, inflation target zones, and the skewness of the distribution of professional forecasters’ inflation forecasts. To this end, we have laid out a simple model of an inflation target zone, and we have used a PSTR model to test the implications of the theoretical model. Our empirical results show that the link between skewness and inflation is in line with the implications of the model. Professional forecasters seem to believe in inflation target zones. Inflation affects skewness negatively within the inflation target zone, and positively outside the boundaries of the inflation target zone. We have also documented differences across countries, and we have studied the robustness of our empirical results across various model specifications. While we have analyzed inflation forecasts for the G7 countries, it would be interesting to extend our research to other inflation targeting countries. In this respect, it might be worth to expand our modeling framework to incorporate country-specific features of IT regimes. For example, the Norwegian IT regime accounts for fluctuations of the exchange rate, implying that it would be interesting to study an open-economy framework. It would also be interesting to examine whether the pattern we have recovered in forecasts of professional forecasters also holds for survey data of households’ forecasts of inflation dynamics. Finally, the correlation between inflation, inflation target zones, and the skewness of the distribution of inflation forecasts that we have detected in our empirical research may transmit onto forecasts of other variables like, for example, forecasts of short-term and long-term interest rates. We leave it to future research to study such transmission effects.
References


APPENDIX

A ADDITIONAL TABLES AND FIGURES
Figure A.1: G7 Panel - Elasticities of Inflation and Demeaned Inflation

Note: Black line: Demeaned inflation (left axis). Red line: Elasticity with respect to contemporaneous and lagged demeaned inflation (right axis).
Note: Black line: Skewness (left axis). Red line: Elasticity with respect to contemporaneous and lagged demeaned inflation (right axis).