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Abstract

This paper studies the effects of inflation targeting (IT) on relative price variability (RPV) using a data set of 20 countries comprising both targeters and nontargeters. We find that a decline in mean inflation after IT adoption is not necessarily associated with a similar fall in RPV, and that what matters most for the structural changes in RPV is the initial inflation regime prior to the adoption of IT rather than IT adoption itself. IT adoption impacts the shape of the underlying relationship between inflation and RPV in countries with initially high inflation rates, moving it from monotonic to the U-shaped profile observed for countries with low inflation regimes. The minimum point of this U-shape curve is indicative of the public's expectations of inflation and is very close to the announced target for inflation in most of the countries we study.

1 Introduction

Variability in relative prices is known to be a major channel through which inflation can induce welfare costs by impeding an efficient allocation of resources in the economy. Consequently, substantial effort has been devoted in the literature to examining the link between relative price variability (RPV) and aggregate inflation. Although much of the existing theoretical and empirical literature points to a positive monotonic relationship, newer contributions suggest that the relationship between inflation and RPV is more complicated, particularly in terms of its sensitivity to the inflation regime.[1]

The primary purpose of this study is to investigate whether the connection between inflation and RPV is influenced in an important way by the monetary policy framework chosen by a central bank. Specifically, this paper focuses on exploring whether the adoption of an inflation targeting (IT) framework exerts any significant impact on RPV, as measured by the standard deviations of sectoral inflation rates relative to the aggregate rate. Since it was first implemented in New Zealand over two decades ago, the popularity of IT has spread, with some 25 countries worldwide implementing the framework to date (Freedman and Laxton 2009). The literature is now replete with studies pointing to reductions in both the level and the volatility of inflation in countries that have adopted IT [e.g. Mishkin and Schmidt-Hebbel 2007].[2] While studies of the impact of IT on aggregate inflation performance are plentiful, little attention has been paid to the impact of IT on RPV.

The question of whether and indeed how IT affects RPV is an important one for several reasons. First, exploring the potential connection between IT and RPV is a worthwhile exercise given the popularity of IT as a monetary framework and the centrality of RPV to the current generation of macro models. The importance of RPV is recognized in standard New Keynesian DSGE models, where the variance of relative prices is viewed as a useful summary statistic. As noted by Amano, Ambler, and Rebei (2007), for example, in DSGE models, the optimal rate of target inflation and the optimal variability of inflation relative to output depend on the quantitative effects of price dispersion on macroeconomic equilibrium. Second, answering the question helps us to identify the driving force behind the change in RPV, distinguishing between IT adoption itself and its subsequent impact on inflation. If the relationship is monotonically positive as is often believed in the literature, one should expect that IT adoption would bring about a decline in RPV in the same way as it has led to a decline in inflation. If the relationship is more complex, however, the effect of IT adoption on reducing RPV may hinge upon the change in inflation regimes after IT adoption. Third, our answer to the question also sheds additional light on the empirical evidence for the relative effectiveness of IT across different stages of development. While there is strong evidence that developing countries benefit more from

IT than industrial countries in combating inflation and its volatility [e.g. Pétursson 2004; Lin and Ye 2009], we are aware of no empirical research that has assessed this issue with respect to RPV.

To address the question, we consider a data set of 20 industrial and developing countries consisting of twelve targeters and eight nontargeters during the so-called great moderation period starting in the mid-1980s. We first find that IT adoption brings about a downward shift in mean inflation in all countries under study, consistent with the literature. The more interesting findings relate to the link between IT adoption and RPV. For countries with initially high inflation rates[3], we find that a fall in mean inflation is associated with a similar decline in RPV after the adoption of IT. In countries with initially low inflation rates, however, RPV changed little, and even increased after IT adoption. This result, as in the recent findings by Choi (2010) and Choi and Kim (2010), suggests that the nature of the connection between inflation and RPV is not monotonic but instead hinges upon inflation regimes, with a linear positive relationship at high trend inflation and a U-shaped relationship in low or moderate inflation environments.[4] A similar story is evident for non-targeting countries, with RPV falling with mean inflation only in the high inflation countries. Combined together, it seems that what matters most for the structural changes in RPV is not the adoption of IT *per se* but the initial inflation environments prior to adopting IT.

Once the structural shift in inflation is taken into account, our regression analysis based on a range of econometric techniques, including semi-parametric regression, parametric regression, and rolling regression, suggests that IT adoption has brought about a tighter connection between inflation and RPV. Put differently, the same shocks to inflation lead to a larger dispersion of relative prices under IT, probably because a stronger commitment to a numerical target for inflation results in a higher degree of nominal rigidity via the sluggish response of inflation expectations. Prices might also have become more rigid after IT adoption due to a fall in average inflation, consistent with the ample empirical evidence on the inverse relationship between the degree of price rigidity and the inflation regime [e.g. Kiley 2000; Nakamura and Steinsson 2008]. If firms set their prices more flexibly in high inflation settings, while maintaining stickier prices in low inflation environments, an increase in the degree of price rigidity could be associated with a larger dispersion of relative prices [e.g. Ball, Mankiw, and Reis 2005]. Since the tighter link between inflation and RPV is also observed in most nontargeters, however, the increased rigidity in price adjustment is posited to be driven more by the fall in mean inflation than by the change in the monetary policy framework itself.

We also find that the underlying relationship between inflation and RPV takes a U-shaped profile in most cases under study, in line with the recent findings by Choi (2010) and Fielding and Mizen (2008). While the U-shaped profile is found in low inflation countries regardless of IT adoption, it is observed in high inflation targeters only after IT adoption. However, no such shift to a U-shaped relationship is observed in the high-inflation nontargeters under study, suggesting that IT makes a major difference in high inflation countries but not in low inflation countries. The U-shaped relationship implies the presence of a point at which RPV is minimized, which we denote as π^* throughout the paper. According to our empirical results, π^* is positive and significantly different from zero in most countries, indicating that the inflation-RPV relationship is U-shaped around a positive inflation rate. RPV, therefore, changes not with the inflation rate *per se* as widely believed in the literature, but with the deviation of the inflation rate from π^* in either direction. In this context, π^* is conceptually related to the central bank's numerical target for inflation [e.g. Ireland 2007] or the inflation target level perceived by the public [e.g. Kozicki and Tinsley 2005]. Given that IT purports to reducing uncertainty about future price developments by strengthening the anchoring of inflation expectations toward a numerical objective, dispersion of relative prices would increase with any departure of inflation from the targeted level.

In fact, we find that the estimates of π^* are well within the announced target range of inflation in most targeting countries, and that $\hat{\pi}^*$ has declined over time as trend inflation did. $\hat{\pi}^*$ is also informative for nontargeters in identifying the public's perception of inflation. Although nontargeters do not announce quantitative inflation objectives, market expectations are formed anyway by what the market believes the unannounced inflation target to be. This is particularly the case for the nontargeters that are widely recognized as *implicit* targeters, where $\hat{\pi}^*$ is found to match well with the implicit target levels of inflation reported by other researchers. In this vein, it is fair to argue that targeters have no clear superiority over implicit targeters with the reputation and commitment for pursuing low inflation when it comes to the anchoring of the public's inflation expectations to a certain intended target level.

The story, however, changes somewhat significantly when we examine the effectiveness of IT in countries with high initial inflation rates. While targeters with high initial inflation could effectively stabilize market expectations of inflation around the targeted level of inflation, there is no clear evidence of stabilizing inflation expectations in their nontargeting counterparts. Given that one of the major criteria for the success of IT is the level of control it exerts on the public's inflation expectations, the potential gains from adopting IT are more pronounced in countries with high inflation rates. Our findings therefore lend credence to the view that adoption of IT is more beneficial to developing countries with typically high inflation rates.

The remainder of the paper is structured as follows. Section 2 describes and presents a preliminary analysis of the data. Section 3 is devoted to a discussion of the econometric analysis of the relationship between RPV and inflation in targeting and non-targeting countries. The robustness of our regression results is also examined in that section. Section 4 discusses the implications of the U-shaped relationship between RPV and inflation with a focus on π^* and its relationship to explicit/implicit target inflation rates. Section 5 concludes the paper. The Appendices contain detailed descriptions of the data.

2 Data and preliminary analysis

The Data

Our data set comprises monthly (quarterly for Australia) indices of national consumer prices and their subaggregates for twelve targeters, Australia (AUS), Brazil (BRA), Canada (CAN), Hungary (HUN), Israel (ISR), Korea (KOR), Mexico (MEX), Norway (NOR), the Philippines (PHL), Sweden (SWE), the United Kingdom (UK), and South Africa (ZAF), along with eight nontargeters, Argentina (ARG), Switzerland (CHE), Germany (GER), Hong Kong (HK), Italy (ITA), Japan (JPN), Turkey (TUR), and the United States (US).[5] The number of subaggregate items varies across countries, from five in TUR to seventeen in ZAF. Data limitations for these subaggregate price indices led us to set the starting year of the sample period at 1984, which marks the onset of the so-called 'Great Moderation' period when the volatility of aggregate economic variables, including inflation, declined significantly in most industrial countries. While the starting point is slightly different for some countries (GER, HUN, TUR, and UK), the end point of the data range is 2009:M2 (2009:Q1 for AUS) in all countries. The sources of the underlying data are listed in Table A.1 in the Appendix, to which further details on the data have been relegated.

Table 1 presents the 20 countries that are categorized based on their initial inflation regime and their adoption of IT.[6] Although it is customary to sort countries into groups of industrial versus developing nations, it is more appropriate here to classify them by their initial inflation regime in view of its potential importance in the inflation-RPV nexus [e.g. Bick and Nautz 2008; Choi 2010]. Throughout the paper, high inflation countries are defined as those with average annual inflation rates greater than ten percent in the pre-IT period, which encompasses BRA, HUN, ISR, PHL, MEX, and ZAF for targeters and ARG and TUR for nontargeters, as listed in Table 1. Our sample therefore comprises twelve low inflation economies and eight high inflation countries.

Inflation is measured in a standard way by calculating annualized percentage changes in the consumer price index. Unless noted otherwise, we concentrate on the deseasonalized month-to-month inflation rates, where the price indices are seasonally adjusted using the Census X12-method.

RPV is then constructed by calculating the standard deviation (s.d.) of the disaggregate inflation rates,[7]

$$RPV_t = \sqrt{\sum_{i=1}^{N} \omega_i (\pi_{it} - \overline{\pi}_t)^2}$$

where $\pi_{it} = \ln P_{it} - \ln P_{i,t-1}$, $\overline{\pi}_t = \sum_{i=1}^{N} \omega_i \pi_{it}$, ω_i denotes the fixed expenditure weight of the i^{th} product that sums to unity, and P_{it} represents the price index of i^{th} good at time t.

Preliminary data analysis

Table 2 presents summary statistics on average inflation and RPV for each country for two subsample periods, where the full sample is split by a certain break point. For targeters, the onset of their IT regime is used as the break point[8], whereas the break points for nontargeters are determined by the Bai-Perron's (1998) multivariate structural break tests for their inflation series, as shown in Table 3.

A couple of observations can be made from Table 2. First, there exists a notable decline in average inflation after the break point in all the countries considered, regardless of IT adoption. This observation accords well with the findings by some earlier studies [e.g. Cecchetti and Debelle 2004; Levin and Piger 2004]. Not surprisingly, the fall in average inflation is more significant in the high inflation countries, from double- or triple- digit annual inflation to single-digit annual inflation. By contrast, no such universal decline is observed in RPV, with a marked decline only seen in high inflation countries. It is a country's initial inflation regime, rather than its IT status, that appears to be important. In countries with low initial inflation rates, a shift in mean inflation is not associated with any comparable reduction in the cross-sectional variation of relative prices. Average RPV has actually increased after the break point in some low inflation countries, including targeters CAN, NOR and the UK, and nontargeters CHE, GER, HK, and US. This finding casts some doubt about the validity of the well-established positive relationship between inflation and RPV.

An essentially similar picture is painted in Figure 1, which portrays the empirical densities of inflation and RPV before (solid line) and after (dashed line) the break point. As can be seen from the plots, there is a remarkable difference between inflation and RPV in their empirical densities. While the distribution of inflation clearly shifts leftward in most countries, reflecting the decline of mean inflation, the distribution of RPV barely shifts after the break, except for the high inflation countries. The structural connection between inflation and RPV captured by comovement of the empirical densities can be found only in the high inflation countries, irrespective of IT adoption.

To throw additional light on this issue, we run the Bai-Perron structural break test on the

RPV series and report the results in Table 3 along with those for inflation. While the outcomes of these tests point strongly to the presence of structural changes in the inflation rates of almost all countries, for RPV, evidence of a structural shift is found mainly in the high inflation countries. Table 3 also reports the estimated dates for the structural breaks in inflation and RPV. Among the eight countries that exhibit structural changes in both inflation rates and RPV, the timing of the decline in inflation roughly matches that of RPV only in the high inflation countries. In some targeters, such as CAN, HUN, KOR, MEX, and UK, the estimated break points in inflation rates are close to the official adoption dates of IT, lending support to the use of the IT adoption date as the break point.[9] In the other targeters, the timing of the decline in mean inflation is a bit earlier than the formal announcement dates of IT adoption. Such a time lead, however, makes intuitive sense if those countries stabilized inflation prior to making an official announcement of IT adoption. Overall, the results from the Bai-Perron method generally corroborate those from Table 2 and Figure 1.

3 Econometric analysis

Our discussion in the previous section suggests that a mean shift in inflation is accompanied by a similar structural change in RPV in the high inflation countries but not in the low inflation countries. This seemingly loose structural connection between inflation and RPV in the low inflation countries, however, does not necessarily imply a collapse of the link between inflation and RPV, especially when the two variables of interest are suspected to undergo some different structural changes. One might then reasonably ask to what extent (if at all) the adoption of IT has impacted RPV, once the structural change in the inflation rate is properly taken into account. To investigate this, the current section utilizes various econometric techniques to carry out a series of regression analyses. We first implement a semi-parametric regression technique to identify the underlying functional form of the relationship between inflation and RPV without imposing any prior assumptions. Based on the information obtained regarding the functional form, we then apply a parametric regression technique to two sub-samples split by the aforementioned break points. As a sensitivity analysis, we also conduct a rolling regression analysis to check the robustness of our regression results to the choice of break points.

Underlying functional form and semiparametric regression analysis

In the literature, the empirical evidence on the positive link between inflation and RPV is largely built upon regression analysis, typically with inflation as the causal factor. A common feature of this existing literature is that the studies focus on linear relationships, although the linearity restriction is often called into question [e.g. Parks 1978; Hartman 1991]. In the absence of any concrete guidance from economic theory, a useful strategy to identify the underlying functional form is to utilize a semi-parametric approach which involves combining the attractive features of both parametric and nonparametric models.[10] Following Fielding and Mizen (2008) and Choi (2010) on which this section largely draws, we consider a partially linear regression model as follows,

$$RPV_t = X_t'\beta + g(\pi_t) + \varepsilon_t, \quad (1)$$

where X_t is a $(p+q) \times 1$ vector of the regressors that includes the lagged terms of RPV and inflation, $X_t' = \{RPV_{t-1}, ..., RPV_{t-p}, \pi_{t-1}, ..., \pi_{t-q}\}$. $g(\cdot)$ is an unknown smooth differential function that captures a contemporaneous effect of inflation on RPV and determines the underlying functional form of the relationship between inflation and RPV. The $g(\cdot)$ function in eq. (1) is estimated semi-parametrically as illustrated by Choi (2010), with a particular emphasis on the estimation of $g'(\cdot)$, the first derivatives of $g(\cdot)$.

Figure 2 plots the semiparametric estimates of the $g'(\cdot)$ function (solid line) along with the dotted horizontal line that captures $g'(\cdot) = 0$. Of interest is the point where the estimated $g'(\cdot)$ function crosses the dotted horizontal line, which corresponds to the RPV-minimizing inflation rate, denoted as π^* throughout the paper. If the inflation rate is below π^*, then $g'(\cdot) < 0$ and $g(\cdot)$ is downward-sloping, while $g'(\cdot) > 0$ and $g(\cdot)$ is upward-sloping if the inflation rate is above π^*. In most cases considered, the fitted $g'(\cdot)$ function is approximately linear and upward sloping, and the transition of $g'(\cdot)$ from negative to positive values indicates that $g(\cdot)$ has a quadratic form. This is particularly the case for the countries with low initial inflation regardless of IT adoption. In those countries, the point where $g(\cdot)$ intersects the dotted horizontal line, or $\hat{\pi}^*$, is lower in the second subsample, implying that the U-shaped relationship shifts leftward as mean inflation falls.

Albeit overwhelming, the evidence of a U-shaped relationship is not ubiquitous. In the countries with high initial inflation, the fitted $g'(\cdot)$ function does not cross the dotted horizontal line but remains consistently above or below it, implying that the $g(\cdot)$ function is not quadratic but more likely monotonic. This is the case for the high inflation targeters (BRA, HUN, ISR, and MEX) before their adoption of IT, and for the high inflation nontargeters (ARG and TUR) in both subsample periods. Notice that the underlying functional form between these two groups of high inflation countries is quite different in the second subsample. While it switches from monotonic to a U-shape in the targeting high inflation countries, no such a transition is observed in the nontargeting high inflation countries. As will be discussed in more detail in Section 4, this result may reflect the difference that IT adoption makes for the countries with high initial inflation.

The U-shaped relationship and parametric regression analysis

Our semi-parametric analysis suggests that a well-specified parametric model of the inflation-RPV nexus should incorporate two features: (i) a structural change in the underlying model; and (ii) a quadratic U-shaped profile. To accommodate the first feature, the full sample is split into two subsamples based on the aforementioned break points. To capture the second feature, we employ the following parametric model,

$$RPV_t = \alpha_0 + \sum_{h=1}^{p} \alpha_h RPV_{t-h} + \beta_1 \pi_t + \beta_2 \pi_t^2 + \sum_{j=1}^{q} \gamma_j \pi_{t-j} + \varepsilon_t. \quad (2)$$

where the lag lengths (p, q) are chosen by the BIC rule.[11] This parametric specification can be seen as general because it nests both linear and quadratic models. If β_2 in eq.(2) approaches zero, the functional form collapses to linear and hence the overall relationship between RPV and inflation is solely determined by β_1. If β_2 is positive, the relationship is U-shaped and the minimum point of U-shape occurs at π^* where $\widehat{RPV}$ takes on its lowest value. As shown by Choi (2010), the minimum point can be estimated by $\hat{\pi}^* = \frac{-\hat{\beta}_1}{2\hat{\beta}_2}$.

An important question regarding the U-shaped relationship is whether it is around zero ($\pi^* = 0$) or around a non-zero inflation rate ($\pi^* \neq 0$). If the association is U-shaped around zero inflation, RPV would monotonically increase with inflation (or deflation) and hence higher inflation causes a larger dispersion of relative prices as documented by a large number of earlier studies. If, instead, the relationship is U-shaped around a nonzero inflation rate, RPV rises not with the inflation rate but with the deviation of inflation from π^*. The further away a shock drives inflation from π^*, the more cross-sectionally dispersed relative prices become. π^* is also useful in tracking the stability of the U-shaped relationship between inflation and RPV by looking at the time-varying behavior of π^*.

The parametric regression results reported in Table 4 warrant several comments. First, in most cases under study, the relationship is U-shaped around a positive inflation rate which is significantly different from zero.[12] As can be seen from the third and fourth columns of the upper panel of Table 4, the impact of inflation volatility on RPV is non-negative ($\hat{\beta}_2 \geq 0$) in all cases, while that of the inflation level is negative ($\hat{\beta}_1 < 0$) in the vast majority of cases, indicative of a U-shaped relationship between inflation and RPV. As presented in the lower-left panel of Table 4, however, $\hat{\beta}_1$ is positive in the pre-break period in both high inflation non-targeting countries and two of the high-inflation targeters, BRA and MEX. In these countries, the corresponding $\hat{\beta}_2$ is very close to zero and thus π^* is not properly defined, suggesting that the underlying relationship is more likely to be positive linear. Apart from them, $\hat{\pi}^*$ is positive and significantly different from zero in all countries, as the lower bound of the 95 percent confidence interval for $\hat{\pi}^*$ is consistently above zero. This result implies that the RPV-related welfare cost of inflation is minimized when the inflation rate is above zero, rather than zero.

Second, the underlying relationship between inflation and RPV is not stable over time, but instead varies across inflation regimes in a systematic manner. This time variation is particularly noticeable in the high inflation targeting countries, where the underlying relationship appears to switch from a positive monotonic relationship ($\hat{\beta}_1 > 0$ and $\hat{\beta}_2 \simeq 0$) in the pre-break period to a U-shaped profile ($\hat{\beta}_1 < 0$ and $\hat{\beta}_2 > 0$) in the post-break period. In the targeters with low initial inflation where the evidence of a U-shaped profile is found in both subsample periods, we note a decrease in the value of $\hat{\pi}^*$, reflecting a leftward shift of the U-shaped relationship. A broadly similar story is told for nontargeters that have maintained low and stable inflation during the great moderation period.

Third, the link between inflation and RPV has become stronger after IT adoption in most targeters, when judged by a larger value of $\hat{\beta}_2$ in the post-IT period. In CAN, for example, the value of $\hat{\beta}_2$ has increased almost six-fold, from 0.26 to 1.55. This increase in $\hat{\beta}_2$ signifies a steeper curvature of the U-shape and hence a larger response of RPV to the same inflation shock that leads to a deviation of inflation from π^*.[13] This result is posited to be driven by an increase in the degree of price rigidity under IT.[14] When inflation expectations are anchored to an announced inflation target, economic agents react more sluggishly to a temporary shock that drives inflation away from the targeted inflation, causing a larger dispersion of relative prices. This stronger response of RPV to inflationary shocks, however, can be also seen from nontargeters, especially from those that maintained low inflation with implicit but credible commitment to low inflation.

Robustness check using rolling regression analysis

To ensure that our results in the previous section are not driven by the choice of specific sample periods, we appeal to the rolling regression approach that doesn't impose any prior restrictions on the timing of break points. This is an attractive feature when the full-sample estimates are vulnerable to time variation in the conditional mean of the inflation process.

Figure 3 presents the estimates of β_1 and β_2 in eq.(2) from a sequence of rolling samples. Each point in the plot exhibits $\hat{\beta}_1$ (thin line) and $\hat{\beta}_2$ (heavy line) at t that are obtained using data from $t-120$ ($t-40$ for AUS) to t with a window of 10 years.[15] The numbers on the horizontal axis therefore represent the beginning year of each 10-year window. For instance, 1984 captures the subsample period of 1984-1993, and so on. As anticipated, the rolling estimates of β_2 are consistently positive, while those of β_1 are negative in most cases, indicating that the relationship between inflation and RPV is U-shaped around a positive π^*. A notable exception, however, can be found in some high inflation countries (BRA, MEX, ARG, and TUR) where $\hat{\beta}_2$ is close to zero in the early part of sample period with $\hat{\beta}_1$ being positive. This suggests that the relationship is positive linear during the corresponding sample period. In MEX for example, a high inflation targeter, $\hat{\beta}_2$ is close to zero until around 1994 while $\hat{\beta}_1$ is positive, implying that the relationship between inflation and RPV in MEX is positive linear until the subsample period of 1994-2003. After 1994, however, $\hat{\beta}_2$ in MEX switches to positive and $\hat{\beta}_1$ swings to negative, indicative of a U-shaped profile.

The rolling estimates for β_1 and β_2 also display a significant variation over time. Our visual inspection suggests that the timing of structural changes in the two coefficient estimates roughly coincides with the changes in the monetary policy regime reported in Table 3. For instance, the timing of the structural change in $\hat{\beta}_2$ is very close to their official adoption dates of IT in some targeters, such as AUS, CAN, KOR, and UK.

4 π^* and target inflation

Our discussion so far suggests that the relationship between inflation and RPV is U-shaped around a nonzero inflation rate in most countries, especially after IT adoption. A central implication of the U-shaped relationship is that RPV changes not with inflation per se, but with the deviation of inflation from π^*. Questions then naturally arise regarding how to interpret the nonzero π^* and how π^* is related to the inflation target. This line of inquiry is pursued in the current section.

Interpretation of π^* *and the inflation target*

In empirical macro models, inflation rates are often partitioned into two parts: (i) its *perceived* equilibrium attractor or the perceived central-bank target for inflation; and (ii) deviations from the equilibrium [e.g. Kozicki and Tinsley 2008]. Since IT purports to reducing uncertainty about future price developments by anchoring inflation expectations toward a numerical objective, the dispersion of relative prices would be minimized if the actual inflation rate is equal to the inflation target. Because RPV would rise with any deviation of actual inflation from the targeted inflation rate in either direction, π^* can be viewed as conceptually related to the target level of inflation perceived by the public [e.g. Kozicki and Tinsley 2005], or the central bank's inflation target [e.g. Ireland 2007].

In light of the fact that *trend* inflation is usually pinned down by a central bank's target in general equilibrium models, π^* is also related to trend inflation [e.g. Cogley and Sbordone 2008; Sbordone 2007].[16] In this context, it would be instructive to examine whether the estimate of π^* is close to the announced target level of inflation.

Table 4 presents the estimates of π^* before and after the break point, along with the explicit/implicit numerical targets for inflation. The results in Table 4 illustrate a couple of interesting points with regard to $\hat{\pi}^*$. First, $\hat{\pi}^*$ appears to have fallen into the target range of inflation after IT adoption in eight out of twelve targeters, probably because a strong commitment to an announced target helps the public to form expectations for the policy outcome [e.g. Woodford 2004]. In the remaining four targeters (AUS, HUN, MEX, and PHL), $\hat{\pi}^*$ stays outside the target range but not far from the upper end of the target. Aside from AUS, this may be because more time is needed for these countries to build credibility around the relatively recently adopted new monetary policy framework.[17]

Second, $\hat{\pi}^*$ is useful for nontargeters in identifying the market perception of the *unannounced* inflation target, particularly in the nontargeters that are generally regarded as *implicit* targeters. Although nontargeters do not announce any quantitative inflation objectives, market expectations are still anchored by what the market believes the inflation target is. For example, some nontargeters, such as CHE, GER, JPN, and US, are widely recognized as *de facto* targeters because their commitment to low inflation or price stability has been deeply embedded in their monetary policy framework [e.g. Truman 2003].[18] As shown in Table 4, the estimates of π^* for these implicit targeters are well within the implied targets ranges reported by other researchers.

Time variation of π^* and trend inflation

Recently, growing evidence has emerged on the shifts in trend inflation over time [e.g. Amano, Ambler, and Rebei 2007; Ireland 2007; Stock and Watson 2007; Cogley and Sbordone 2008]. Based on a macro model with a time-varying inflation trend, for instance, Cogley and Sbordone (2008) maintain that trend inflation in the U.S. has been nonzero and varied over time. A similar conclusion is reached by Stock and Watson (2007) based on an unobserved component trend-cycle model with stochastic volatility. Using the Kalman filter technique, Leigh (2008) also documents that the Fed's implicit target is not constant but instead has varied significantly over time, from near 3% in the early 1980s, to 3-4% in the late 1980s and early 1990s, and to 1-2% after the 1990-1991 recession, before rising to 2-3% during 2001-2004. Similarly, Ireland (2007) reports that the Fed's inflation target has increased from 1.25% in 1959 to more than 8% in the late 1970s, followed by a gradual reduction to below 2.5% in 2004. This time variation of trend inflation is often explained by the central bank's updating its policy rule when it learns more about the structure of the economy.[19] For example, Levin and Piger (2004) assert that movements in the mean of inflation reflect shifts in private agent perceptions of the policy target for inflation. Since the central bank's inflation target bears particular relevance for the inflation expectations of the public, it would be of interest to examine how closely the estimates of π^* match the expected inflation of economic agents.

Given the availability of a direct measure of inflation expectations for the US, we use that country as a case study. Figure 4 reports the result of this exercise by plotting the evolution of $\hat{\pi}^*$ in the U.S. for a 10-year rolling window sample, together with the long-horizon inflation expectations from the Survey of Professional Forecasters.[20] As can be seen from the figure, π^* fits quite well the survey measures of long-horizon inflation expectations in the U.S., confirming our prior intuition that π^* is closely related to the inflation expectations of the public. The time-varying patterns of both $\hat{\pi}^*$ and inflationary expectations of the public are believed to be commonly driven by the changes in the central-bank target for inflation. Unfortunately, data for long-term inflation expectations are not available in many other countries under study. This led us to utilize the period average inflation as a rough substitute for the market expectation of inflation. As depicted in Figure 4, the period average inflation rates (dotted line) are closely linked to the expected inflation rates in the U.S.

Figure 5 plots the evolution of $\hat{\pi}^*$ (heavy solid line) over time, together with the sample average inflation rates (dotted line) and the targeted level/band of inflation (thin solid line) for all the countries under study. Since $\hat{\pi}^*$ is not properly defined in the high inflation countries before IT adoption with $\hat{\beta}_2$ close to zero, we concentrate on the post-IT period for those high inflation countries. A couple of important features emerge from Figure 5.

First, $\hat{\pi}^*$ has steadily declined over time in most countries, in a similar pattern to that exhibited by period average inflation. In some countries, especially in US, JPN, and HK, $\hat{\pi}^*$ moves in sync with the period average inflation rates, consistent with the recent empirical evidence on time-varying trend inflation. In the two nontargeting high inflation countries (ARG and TUR), however, $\hat{\pi}^*$ diverges from the period average inflation rate, most likely due to a weak anchoring of inflation expectations in those countries.

Second and more important, $\hat{\pi}^*$ is already within the announced target range of inflation in all of the low inflation targeters, with the exception of AUS and NOR where $\hat{\pi}^*$ recently moved out of the target range. This may mirror the indirect evidence of IT's effectiveness in reducing inflation expectations toward the announced target after IT adoption. Some targeters managed to contain inflation expectations within a prescribed narrow band in a relatively short time, although it appears to have taken a bit longer in others. In CAN, for instance, $\hat{\pi}^*$ fell rapidly below the targeted inflation level right after the adoption of IT, indicative of a quick adjustment of the public's inflation expectations after the adoption of the new monetary policy framework. A broadly similar pattern is observed in the nontargeting countries that are widely known as *de facto* targeters. In CHE, GER, ITA, JPN, and US, for example, $\hat{\pi}^*$ is well within their implicit target range for inflation estimated by other researchers. Our result therefore supports the finding by Ball and Sheridan (2005) that targeters do not necessarily entertain a clear advantage in anchoring inflation expectations, compared to the nontargeters that have maintained low and stable inflation without explicitly adopting IT.

The story, however, changes somewhat significantly when we look at the countries with high initial inflation rates. Although $\hat{\pi}^*$ in some high inflation targeters (HUN, MEX, PHL) is yet to fall within the target range, it seems to be moving toward it after IT adoption. This may be because they are still building the credibility of the new monetary policy framework having adopted IT relatively recently. By contrast, no such pattern of moving toward a certain level of inflation can be seen in their nontargeting counterparts. Interestingly, a significant difference exists between the two nontargeting high inflation countries. While $\hat{\pi}^*$ consistently deviates from the sample average inflation rate in ARG, the gap between $\hat{\pi}^*$ and the sample average inflation has diminished steadily over time in TUR. This difference may rest on the fact that TUR has adopted IT in 2006, but is considered here as a nontargeter. These results, therefore, support our prior intuition that IT serves to reshape inflation expectations, particularly in initially high inflation countries without a well-defined numerical inflation objectives.

Overall, our results highlight the informativeness of $\hat{\pi}^*$ regarding inflation expectations formed by economic agents in both targeters and nontargeters. $\hat{\pi}^*$ is instrumental in identifying the public's expectations of inflation for nontargeters, while, for targeters, in assessing the effectiveness of IT in establishing a credible nominal anchor. Given that one of the major criteria for the success of IT is the level of control it exerts on the public's inflation expectations, our results offer qualitative support for the view that IT is more beneficial to countries with initially high inflation rates.

5 Concluding remarks

Inflation targeting has become a popular monetary policy framework in the past two decades, largely for its success in reducing both inflation and inflation volatility. This paper investigates whether and how the adoption of IT exerts a significant influence on the variability of relative prices as it did on inflation. Grappling with this question is crucial not just in evaluating the effectiveness of IT beyond its impact on aggregate inflation, but in understanding the transmission mechanism of inflation as a key element of the standard New Keynesian DSGE models.

By examining twelve targeting countries and eight nontargeting countries, we first find that what matters for RPV is not IT adoption *per se* but the inflation regime prior to the adoption of IT. RPV has fallen with mean inflation rates only in the countries with high initial inflation rates, regardless of whether they targeted inflation or not. Once the structural change in inflation is accounted for, however, our regression analysis suggests that the connection between inflation and RPV has become tighter after IT adoption, with the same shocks to inflation leading to a larger dispersion of relative prices. This tighter relationship in the later sub-sample is not unique to inflation targeters, however.

We also find that the relationship between inflation and RPV takes a U-shaped profile around a non-zero inflation rate in most of the countries under study. An important implication of this is that RPV changes not with the inflation rate as widely accepted in the literature, but with the deviation of inflation from π^* at which RPV is minimized. Insofar as economic agents anchor their expectations of inflation around the target level, relative prices would become more dispersed as the public responds more sluggishly to the shocks that drive actual inflation away from the targeted level. In this vein, π^* can be viewed as conceptually related to the inflation target level perceived by the public, and to trend inflation which is often pinned down by a central bank's target. Our estimates of π^* are also informative about the market perception of the unannounced inflation target in nontargeting countries. For low-inflation nontargeters, we find that the estimates of π^* match quite well with the implicit inflation targets reported by other researchers.

When it comes to the anchoring of inflation expectations as measured by π^*, therefore, targeters seem to have no clear advantage over the implicit targeters with a comparable commitment to low inflation. The effectiveness of IT, however, stands out when countries with high initial inflation rates are considered. While IT serves to anchor inflation expectations in the targeters with high initial inflation rates, no clear signs of stabilization of inflation expectations are observed in their non-targeting counterparts. Our findings therefore support the argument that adoption of IT is potentially more beneficial to developing countries with typically high inflation rates.

References

[1] Amano, Robert, Steve Ambler, and Nooman Rebei. 2007. The Macroeconomic Effects of Nonzero Trend Inflation. *Journal of Money, Credit and Banking* 39: 1821–38.

[2] Bai, Jushan, and Pierre Perron. 1998. Estimating and Testing Linear Models with Multiple Structural Changes. *Econometrica* 66: 47–78.

[3] Ball, Laurence, and Niamh Sheridan. 2005. Does Inflation Targeting Matter? In *The Inflation Targeting Debate*, edited by Ben S. Bernanke and Michael Woodford. Chicago, IL: University of Chicago Press, pp. 249-82.

[4] Ball, Laurence, N. Gregory Mankiw, and Ricardo Reis. 2005. Monetary Policy for Inattentive Economies. *Journal of Monetary Economics* 52: 703–25.

[5] Becker, Sascha S., and Dieter Nautz. 2009. Inflation and Relative Price Variability: New Evidence for the United States. *Southern Economic Journal* 76: 146–64.

[6] Bernanke, Ben. S., Thomas Laubach, Frederic S. Mishkin, and Adam S. Posen. 1999. *Inflation Targeting: Lessons from the International Experience*. Princeton, NJ: Princeton University Press.

[7] Bick, Alexander, and Dieter Nautz. 2008. Inflation Thresholds and Relative Price Variability: Evidence from U.S. Cities. *International Journal of Central Banking* 4: 61–76.

[8] Cecchetti, Stephen, and Guy Debelle. 2004. Has the Inflation Process Changed? *mimeo*, Bank for International Settlements.

[9] Choi, Chi-Young. 2010. Reconsidering the Relationship between Inflation and Relative Price Variability. *Journal of Money, Credit and Banking* 42: 769–98.

[10] Choi, Chi-Young, and Young S. Kim. 2010. Is There Any Asymmetry in the Effect of Inflation on Relative Price Variability? *Economics Letters* 108: 233–36.

[11] Clarida, Richard H., Jordi Galí, and Mark L. Gertler. 1998. Monetary Policy Rules in Practice: Some International Evidence. *European Economic Review* 42: 1033–67.

[12] Cogley, Timothy, Giorgio E. Primiceri, and Thomas J. Sargent. 2010. Inflation-Gap Persistence in the U.S. *American Economic Journal: Macroeconomics* 2: 43–69.

[13] Cogley, Timothy, and Argia M. Sbordone. 2008. Trend Inflation, Indexation, and Inflation Persistence in the New Keynesian Phillips Curve. *American Economic Review* 98: 2101–26.

[14] Fielding, David, and Paul Mizen. 2008. Evidence on the Functional Relationship between Relative Price Variability and Inflation with Implications for Monetary Policy. *Economica* 75: 683–99.

[15] Freedman, Charles, and Douglas Laxton. 2009. Why Inflation Targeting? IMF Working Paper No. 09-86.

[16] Goodfriend, Marvin. 2003. Inflation Targeting in the United States. NBER Working Paper No. 9981.

[17] Grier, Kevin B., and Mark J. Perry. 1996. Inflation, Inflation Uncertainty, and Relative Price Dispersion: Evidence from Bivariate GARCH-M Models. *Journal of Monetary Economics* 38: 391–405.

[18] Hartman, Richard. 1991. Relative Price Variability and Inflation. *Journal of Money, Credit and Banking* 23: 185–205.

[19] Ireland, Peter N. 2007. Changes in the Federal Reserve's Inflation Target: Causes and Consequences. *Journal of Money, Credit and Banking* 39: 1851–82.

[20] Kiley, Michael T. 2000. Endogenous Price Stickiness and Business Cycle Persistence. *Journal of Money, Credit and Banking* 32: 28–53.

[21] Kozicki, Sharon, and Peter A. Tinsley. 2005. Permanent and Transitory Policy Shocks in an Empirical Macro Model with Asymmetric Information. *Journal of Economic Dynamics & Control* 29: 1985–2015.

[22] Kozicki, Sharon, and Peter A. Tinsley. 2008. Term Structure Transmission of Monetary Policy. *North American Journal of Economics and Finance* 19: 71–92.

[23] Kuzin, Vladimir. 2006. The Inflation Aversion of the Bundesbank: A State Space Approach. *Journal of Economic Dynamics & Control* 30: 1671–86.

[24] Lastrapes, William D. 2006. Inflation and the Distribution of Relative Prices: The Role of Productivity and Money Supply Shocks. *Journal of Money, Credit and Banking* 38:, 2159–98.

[25] Leigh, Daniel. 2008. Estimating the Federal Reserve's Implicit Inflation Target: A State Space Approach. *Journal of Economic Dynamics & Control* 32: 2013–30.

[26] Levin, Andrew T., and Jeremy M. Piger. 2004. Is Inflation Persistence Intrinsic in Industrial Economies? ECB Working Paper No. 334.

[27] Lin, Shu, and Haichun Ye. 2009. Does Inflation Targeting Really Make A Difference in Developing Countries? *Journal of Development Economics* 89: 118–23.

[28] Mishkin, Frederic S., and Klaus Schmidt-Hebbel. 2007. Does Inflation Targeting Make a Difference? NBER Working Paper No. 12876.

[29] Nakamura, Emi and Jón Steinsson. 2008. Five Facts About Prices: A Reevaluation of Menu Cost Models. *Quarterly Journal of Economics* 123: 1415–64.

[30] Parks, Richard W. 1978. Inflation and Relative Price Variability. *Journal of Political Economy* 86: 79–95.

[31] Parsley, David C. 1996. Inflation and Relative Price Variability in the Short and Long Run: New Evidence from the United States. *Journal of Money, Credit and Banking* 28: 323–41.

[32] Pétursson, Thórarinn G. 2004. The Effects of Inflation Targeting on Macroeconomic Performance. Central Bank of Iceland Working Paper No. 23.

[33] Sbordone, Argia M. 2007. Inflation Persistence: Alternative Interpretations and Policy Implications. *Journal of Monetary Economics* 54: 1311–39.

[34] Stock, James H., and Mark W. Watston. 2007. Why Has U.S. Inflation Become Harder to Forecast? *Journal of Money, Credit and Banking* 39: 3–33.

[35] Truman, Edwin M. 2003. Inflation Targeting in the World Economy. Institute for International Economics.

[36] Vining, Daniel R, Jr., and Thomas C. Elwertowski. 1976. The Relationship between Relative Prices and the General Price Level. *American Economic Review* 66: 699–708.

[37] Woodford, Michael. 2004. Inflation Targeting and Optimal Monetary Policy. Federal Reserve Bank of St. Louis *Review*. 86: 15–41.

Notes

[1]Since the work of Vining and Elwertowski (1976), a sizable literature documents a positive relationship between inflation and the cross sectional variability of relative prices for many countries and for various time periods. See Lastrapes (2006) and Becker and Nautz (2009) for more recent empirical evidence on the positive relationship. Choi (2010), however, recently reports empirical evidence that the relationship is not only non-monotonic but also exhibits significant variation over inflation regimes.

[2]For an opposing view, see Ball and Sheridan (2005) who find little evidence that IT improves macroeconomic performance for a group of OECD countries.

[3]As is formally defined in Section 2.1, we consider high inflation as an average annual inflation rate higher than ten percent before the adoption of IT.

[4]Using simulation experiments, Choi (2010) shows that a modified Calvo model which embeds sectoral heterogeneity in price rigidity can explain this feature of data.

[5]The selection of countries was mainly guided by the availability of sufficiently long continuous data series for subaggregate consumer price indices. Turkey adopted IT in January 2006, but is counted as a nontargeter in our study because it was a nontargeter for most of our sample period.

[6]We follow much of the literature in categorizing targeters based on *de jure* rather than *de facto* targeting.

[7]Since inflation data is used for RPV, the term relative *inflation* variability is more appropriate. Throughout the paper, however, we follow the convention in the literature and call this measure relative *price* variability (RPV), the term that has been ingrained in the literature since the gold-standard era. In fact, the literature reports largely similar results for the inflation-RPV nexus when price-level data are used for constructing RPV [e.g. Parsley 1996].

[8]The exact timing of IT adoption varies with the definition of targeting. While some authors [e.g. Bernanke et al. 1999] date the start of targeting at the point when targets were first announced, some others [e.g. Ball and Sheridan 2005] date based on actual implementation, which often lags the announcements. Here we stick to the former approach, but the difference between the two dates is not consequential in most countries under scrutiny.

[9]Due to the substantive heterogeneity observed in the break points across country, panel data analysis is of reduced merit here as the subsample panels would become 'unbalanced' or 'incomplete', which either imposes a serious limitation in the efficiency gain or makes the estimation infeasible. This problem is known to be exacerbated in dynamic panel models containing lagged terms of dependent variables as in our case.

[10]By combining the easy interpretability of the parametric approach with some of the flexibility of the nonparametric approach, the semiparametric approach is known to get around the so-called 'curse of dimensionality' problem while allowing for flexibility in functional form.

[11] Inclusion of the square term of inflation (π_t^2) is also consistent with the findings by some earlier studies [e.g. Parks 1978; Hartman 1991] that inflation volatility is a significant explanatory variable of RPV.

[12] This is consistent with the point made by Sbordone (2007) that trend inflation, no matter how it is defined, has rarely been zero over past decades, even when a 1% upward bias is allowed for in the measured inflation rate.

[13] As shown in Choi (2010), the *marginal effect* of a deviation of inflation from π^* can be approximated by $\frac{\Delta \mathrm{RPV_t}}{\Delta \pi_t^d} \approx 2\beta_2 \pi_t^d$ which solely depends on β_2, where $\pi_t^d = \pi_t - \pi^*$ denotes the inflation deviation. While the table only includes the *contemporaneous* effect of inflation on RPV, we find qualitatively similar results for the *cumulative* effect regarding the greater impact in the post-break period. We also find that adding country characteristic variables as regressors does not alter much the conclusions reached in this paper. These results are not reported here to preserve space, but are available from the authors upon request. The authors are grateful to an anonymous referee for bringing these issues to our attention.

[14] The potential impact of nominal rigidities on the inflation-RPV nexus can be analyzed separately from that of sectoral productivity or demand shocks within a VAR framework as in Lastrapes (2006). This important issue, however, is left for future research as it goes beyond the scope of the current paper.

[15] Similar results are obtained using rolling windows of 8 and 12 years.

[16] The deviation of inflation from π^* is also similar in spirit to the *inflation gap* described by Cogley, Primiceri, and Sargent (2010) and Sbordone (2007). Cogley, Primiceri, and Sargent (2010) define the inflation gap as deviations of inflation from a time-varying inflation trend. Alternatively, the deviation can be viewed as the gap between actual inflation and expected inflation as in Grier and Perry (1996).

[17] According to the Reserve Bank of Australia's statements on monetary policy, AUS experienced a large deviation of inflation from the target level in the early 2000s mainly due to higher oil prices and tax changes. A Goods and Service tax (GST) introduced in July 2000 to replace the existing wholesale sales tax (WST) has led to large increases in price indices between June 2000 and September 2001.

[18] Although the Fed has never officially stated a target range of inflation, many observers suggest that the Fed has in fact practiced *implicit* inflation targeting during the Volcker-Greenspan era [e.g. Goodfriend 2003]. Clarida, Galí, and Gertler (1998) report that the estimate of the Federal Reserve's unobserved implicit inflation target is around 4%. According to Kuzin (2006), the German Bundesbank's implicit inflation target was more than 4% in 1975 but declined to near 2% in 1998. In Japan, it is broadly recognized that the Bank of Japan views 0-2% as the appropriate level of inflation in the medium to long run (http://www.boj.or.jp/en/type/release/zuiji_new/k060309b.htm).

[19] As pointed out by Ireland (2007), transitory movements in the measured rate of inflation can be driven by various shocks, but large and persistent movements in inflation cannot occur without the help of monetary policy.

[20]The sequence of ten-year-ahead inflation expectations is a widely reported measure of long-run inflation expectations, which was downloaded from the website of the Federal Reserve Bank of Philadelphia (http://www.phil.frb.org/).

Table 1: Country classification

	ITers	non-ITers
low inflation	[6] AUS, CAN, KOR, NOR, SWE, UK	[6] CHE, GER, HK, ITA, JPN, US
high inflation	[6] BRA, HUN, ISR, MEX, PHL, ZAF	[2] ARG, TUR

Note: Numbers in the bracket represent the number of countries in the group. High inflation countries are defined as those with average annual inflation rates greater than 10 percent before IT adoption (for ITers) or breakpoints (for non-ITers).

Table 2: Summary Statistics for Inflation and RPV

	Month-to-month				12-month			
	Inflation		RPV		Inflation		RPV	
	Pre-IT	Post-IT	Pre-IT	Post-IT	Pre-IT	Post-IT	Pre-IT	Post-IT
AUS	1.42 [0.84]	0.67 [0.56]	1.11 [0.48]	0.89 [0.44]	5.73 [2.69]	2.69 [1.42]	2.86 [1.22]	2.45 [0.88]
BRA	12.14 [11.34]	0.56 [0.41]	2.26 [1.86]	0.47 [0.26]	**151.35** [117.56]	6.80 [2.93]	11.18 [6.62]	3.18 [1.01]
CAN	0.34 [0.27]	0.15 [0.26]	0.40 [0.27]	0.45 [0.33]	4.08 [1.15]	2.06 [1.15]	1.60 [0.66]	1.93 [1.01]
HUN	1.34 [0.66]	0.42 [0.34]	0.71 [0.59]	0.57 [0.45]	**16.24** [5.49]	5.46 [1.79]	4.28 [1.30]	3.57 [1.24]
ISR	3.06 [4.66]	0.21 [0.47]	1.48 [1.02]	0.81 [0.37]	**35.90** [48.97]	2.73 [2.83]	5.90 [2.50]	3.10 [1.05]
KOR	0.47 [0.42]	0.24 [0.30]	0.63 [0.38]	0.60 [0.31]	5.53 [2.01]	3.16 [1.51]	3.42 [1.00]	2.78 [0.75]
MEX	2.61 [2.26]	0.37 [0.20]	0.86 [0.78]	0.36 [0.19]	**31.16** [24.28]	4.59 [0.99]	5.27 [3.51]	1.87 [0.58]
NOR	0.32 [0.25]	0.15 [0.43]	0.41 [0.26]	0.65 [0.50]	3.82 [2.12]	1.90 [1.34]	2.07 [0.71]	3.17 [1.04]
PHL	0.88 [1.10]	0.44 [0.42]	0.58 [0.52]	0.41 [0.28]	**10.48** [9.20]	5.35 [2.49]	3.40 [1.37]	2.29 [1.29]
SWE	0.51 [0.51]	0.12 [0.29]	0.72 [0.65]	0.54 [0.33]	6.24 [2.47]	1.60 [1.35]	3.15 [1.55]	2.60 [0.85]
U.K.	0.46 [0.33]	0.16 [0.17]	0.38 [0.19]	0.44 [0.19]	6.04 [1.37]	1.92 [0.76]	2.16 [0.55]	2.71 [0.77]
ZAF	0.90 [0.52]	0.49 [0.45]	1.02 [0.76]	0.83 [0.47]	**11.07** [3.72]	5.83 [3.19]	4.80 [1.85]	4.53 [1.43]
ARG	15.64 [15.45]	0.58 [1.33]	2.86 [2.07]	0.64 [0.54]	**193.93** [115.27]	10.45 [20.16]	11.18 [4.44]	3.76 [2.78]
CHE	0.27 [0.24]	0.08 [0.20]	0.41 [0.30]	0.42 [0.35]	3.19 [1.68]	1.80 [0.47]	1.04 [0.77]	1.76 [0.85]
GER	0.25 [0.28]	0.12 [0.20]	0.37 [0.40]	0.45 [0.36]	2.86 [1.45]	1.54 [0.67]	1.78 [0.78]	2.18 [0.85]
H.K.	0.61 [0.38]	-0.03 [0.56]	0.56 [0.30]	0.91 [0.96]	7.49 [2.35]	-0.13 [3.09]	2.73 [0.51]	3.42 [1.79]
ITA	0.51 [0.21]	0.19 [0.11]	0.32 [0.22]	0.23 [0.12]	5.96 [1.84]	2.41 [0.75]	1.51 [0.60]	1.18 [0.47]
JPN	0.13 [0.30]	0.00 [0.23]	0.39 [0.26]	0.33 [0.24]	1.58 [1.13]	0.06 [0.86]	1.54 [0.59]	1.31 [0.49]
TUR	4.67 [2.11]	1.63 [1.34]	2.48 [1.30]	1.43 [0.85]	**57.28** [11.40]	21.67 [13.60]	8.24 [2.69]	5.87 [1.88]
U.S.	0.27 [0.18]	0.21 [0.34]	0.25 [0.16]	0.46 [0.47]	3.23 [1.12]	2.79 [1.03]	1.40 [0.67]	1.86 [1.02]

Note: The entries are the mean values of inflation rates and RPV during the corresponding period and the numbers in brackets denote their standard deviations. For non-ITers, the breakpoints are determined by the Bai-Perron's (1998) multivariate structural break tests for inflation series. Bold face indicates the high inflation countries and their average annual inflation rates during the pre-IT period.

Table 3: Results of the Bai-Perron Test

	IT-adoption date	Inflation		RPV	
		Break date	CI	Break date	CI
AUS	1993:Q2	1990:Q4	[90:Q1-91:Q4]	-	-
BRA	1999:M6	1994:M6	[94:M6-00:M9]	1992:M3	[92:M3-95:M5]
				1996:M2	[96:M12-96:M6]
				2003:M8	[03:M1-06:M12]
CAN	1991:M2	1991:M1	[89:M8-91:M7]	-	-
HUN	2001:M6	1997:M7	[97:M5-98:M4]	-	-
		2001:M7	[00:M10-02:M6]		
ISR	1997:M6	-	-	1987:M9	[87:M7-90:M6]
				1993:M4	[92:M10-94:M11]
KOR	1998:M4	1998:M3	[97:M1-02:M12]	-	-
MEX	2001:M1	1988:M4	[87:M12-89:M12]	1990:M1	[89:M12-91:M1]
		1999:M3	[99:M3-05:M7]		
NOR	2001:M3	1989:M7	[88:M8-90:M3]	2001:M1	[97:M8-01:M9]
PHL	2002:M1	-	-	-	-
SWE	1993:M1	1991:M12	[91:M7-92:M11]	-	-
U.K.	1992:M10	1992:M1	[91:M11-92:M8]	2005:M12	[03:M8-06:M7]
ZAF	2000:M2	1993:M5	[92:M5-93:M9]	-	-
ARG		1991:M4	[91:M4-96:M2]	1991:M6	[91:M6-93:M2]
CHE		1988:M12	[88:M1-89:M9]	-	-
		1993:M6	[93:M3-93:M12]		
GER		1992:M10	[92:M8-94:M4]	-	-
H.K.		1997:M3	[96:M9-97:M5]	-	-
ITA		1995:M11	[95:M9-96:M7]	1991:M10	[90:M8-94:M7]
JPN		1993:M8	[91:M12-96:M2]	-	-
TUR		2002:M3	[02:M2-02:M9]	2000:M12	[00:M9-01:M12]
U.S.		1999:M9	[97:M12-00:M10]	-	-

Note: 'IT-adoption' represents the month (quarter for AUS) and year of the inflation target announcement as explained in section 2.2. Entries represent the occurrence of break points in the year and month estimated by the sequential procedure estimation method of Bai and Perron (1998,2003). In brackets are the 90% confidence intervals (CI) for the end dates. We consider a partial structural change model of $y_t = x_t'\beta + z_t'\delta_j + u_t$ with $t = T_{j-1}+1, ..., T_j$, by setting RPV or inflation as y_t, the lagged terms of dependent variable as x_t, and constant term as z_t such that the coefficients for the constant term are allowed to shift. By adding lagged terms of dependent variable as regressors, no serial correlation is assumed in the errors terms, $\{u_t\}$. Following the guidelines from Bai and Perron, we assume that the break does not occur during the initial 15 percent nor the final 15 percent of the sample period in testing for structural breaks. The maximum number of breaks is set to five and minimum regime size to 5 percent of sample. Robust standard errors used based on a quadratic spectral kernel HAC estimator with AR(1) prewhitening filters. An entry of "-" indicates that the series does not exhibit a statistically significant break.

Table 4: Parametric regression results

	Full sample					Numerical target
	(p,q)	$\hat{\beta}_1$ (s.e.)	$\hat{\beta}_2$ (s.e.)	$\hat{\pi}^*$	[5%,95%]	(%)
AUS	(1,0)	-0.44 (0.02)	0.21 (0.00)	4.3‡	[3.1, 5.4]	2-3 (since 1993)
BRA	(1,0)	0.09 (0.00)	0.00 (0.00)	351.6‡	[242.6, 460.6]	2.5-6.5 (since 2005))
CAN	(1,0)	-0.44 (0.00)	0.54 (0.00)	4.9‡	[3.7, 6.1]	1-3 (since 1994)
HUN	(1,0)	-0.15 (0.01)	0.19 (0.00)	4.7‡	[-0.3, 9.7]	2-4 (since 2006)
ISR	(2,9)	0.04 (0.00)	0.01 (0.00)	-40.2	[-156.5, 76.2]	1-3 (since 2003)
KOR	(1,0)	-0.40 (0.01)	0.60 (0.00)	4.0‡	[3.1, 4.9]	2-4 (since 2003)
MEX	(1,2)	0.27 (0.00)	0.01 (0.00)	-270.0	[-702.6, 162.5]	3 (since 2003)
NOR	(1,0)	-0.54 (0.00)	0.86 (0.00)	3.8‡	[3.1, 4.4]	2.5 (since 2001)
PHL	(7,0)	-0.20 (0.00)	0.22 (0.00)	5.4‡	[3.5, 7.4]	2.5-4.5 (since 2009)
SWE	(3,0)	-0.23 (0.00)	0.48 (0.00)	2.8‡	[1.5, 4.2]	1-3 (since 1993)
U.K.	(3,0)	-0.16 (0.00)	0.25 (0.00)	3.7‡	[1.5, 5.9]	2 (since 1997)
ZAF	(1,0)	-0.42 (0.02)	0.39 (0.00)	6.5‡	[4.0, 8.9]	3-6 (since 2006)
ARG	(5,2)	0.02 (0.00)	0.00 (0.00)	653.2‡	[225.9,1080.5]	n.a.
CHE	(3,0)	-0.54 (0.01)	1.32 (0.02)	2.4‡	[1.9, 3.0]	2
GER	(1,0)	-0.25 (0.02)	1.06 (0.02)	1.4‡	[0.2, 2.7]	2
H.K.	(1,0)	-0.35 (0.00)	0.45 (0.00)	3.0‡	[2.0, 3.9]	n.a
ITA	(1,0)	-0.32 (0.01)	0.72 (0.02)	2.6‡	[1.7, 3.6]	2
JPN	(1,0)	-0.15 (0.00)	0.60 (0.00)	1.5‡	[0.6, 2.4]	0-2
TUR	(1,0)	0.31 (0.00)	0.00 (0.00)	1714.4	[-9371, 12800]	2-6
U.S.	(4,0)	-0.53 (0.00)	1.17 (0.00)	2.7‡	[2.4, 3.1]	2-3

	Before break					After break				
	(p,q)	$\hat{\beta}_1$ (s.e.)	$\hat{\beta}_2$ (s.e.)	$\hat{\pi}^*$	[5%,95%]	(p,q)	$\hat{\beta}_1$ (s.e.)	$\hat{\beta}_2$ (s.e.)	$\hat{\pi}^*$	[5%,95%]
AUS	(1,0)	-0.64 (0.09)	0.26 (0.01)	5.0‡	[3.6, 6.4]	(1,0)	-0.34 (0.03)	0.19 (0.00)	3.7‡	[1.4, 5.9]
BRA	(1,0)	0.07 (0.00)	0.00 (0.00)	359.8‡	[165.0, 554.5]	(2,0)	-0.10 (0.01)	0.22 (0.00)	2.8	[-2.0, 7.7]
CAN	(1,0)	-0.10 (0.03)	0.26 (0.01)	2.4	[-4.3, 9.0]	(1,0)	-0.51 (0.00)	1.55 (0.01)	2.0‡	[1.5, 2.5]
HUN	(1,0)	-0.02 (0.04)	0.15 (0.00)	0.7	[-14.5, 15.9]	(1,0)	-0.58 (0.02)	0.81 (0.01)	4.3‡	[2.7, 5.9]
ISR	(2,9)	-0.01 (0.00)	0.01 (0.00)	-16.7	[-138.9, 105.5]	(1,0)	-0.06 (0.01)	0.12 (0.00)	2.4	[-5.4, 10.1]
KOR	(1,0)	-0.56 (0.01)	0.68 (0.00)	4.9‡	[4.0, 5.9]	(1,0)	-0.25 (0.01)	0.75 (0.03)	2.0‡	[0.6, 3.4]
MEX	(1,2)	0.29 (0.01)	0.01 (0.00)	-283.7	[-888.0, 320.7]	(1,0)	-1.75 (0.05)	2.36 (0.09)	4.4‡	[4.1, 4.8]
NOR	(1,0)	-0.33 (0.02)	0.56 (0.02)	3.6‡	[2.0, 5.2]	(4,0)	-0.30 (0.01)	0.76 (0.00)	2.4‡	[1.3, 3.5]
PHL	(7,0)	-0.18 (0.00)	0.21 (0.00)	5.4‡	[3.0, 7.9]	(1,0)	-0.49 (0.01)	0.50 (0.00)	5.7‡	[4.4, 7.0]
SWE	(3,0)	-0.21 (0.02)	0.47 (0.00)	2.7	[-0.2, 5.7]	(1,0)	-0.21 (0.01)	0.66 (0.02)	1.9‡	[0.1, 3.7]
U.K.	(1,0)	-0.10 (0.02)	0.22 (0.00)	2.8	[-3.9, 9.6]	(1,0)	-0.34 (0.01)	1.50 (0.05)	1.3‡	[0.8, 1.9]
ZAF	(1,0)	-0.25 (0.04)	0.30 (0.01)	6.3‡	[2.8, 9.8]	(1,0)	-0.88 (0.02)	0.87 (0.01)	6.0‡	[4.2, 7.1]
ARG	(1,1)	0.04 (0.00)	0.00 (0.00)	796.9‡	[175.4, 1418.4]	(8,0)	-0.02 (0.00)	0.04 (0.00)	3.3	[-4.5, 11.0]
CHE	(1,3)	-0.47 (0.02)	1.11 (0.04)	2.5‡	[1.6, 3.5]	(3,0)	-0.51 (0.01)	1.94 (0.08)	1.6†	[0.9, 2.2]
GER	(3,0)	-0.42 (0.04)	1.11 (0.02)	2.3‡	[0.4, 4.1]	(1,0)	-0.32 (0.02)	2.02 (0.13)	1.0‡	[0.2, 1.7]
H.K.	(1,0)	-0.38 (0.00)	0.39 (0.00)	5.4‡	[4.1, 6.6]	(1,1)	0.40 (0.06)	0.61 (0.02)	-1.9‡	[-3.3, -0.5]
ITA	(1,0)	-0.09 (0.19)	0.46 (0.17)	1.2	[-7.8, 10.3]	(1,0)	-0.76 (0.02)	2.40 (0.12)	1.9‡	[1.5, 2.3]
JPN	(1,0)	-0.18 (0.01)	0.56 (0.01)	1.9‡	[0.6, 3.1]	(1,0)	-0.03 (0.00)	1.92 (0.06)	0.1	[-0.3, 0.5]
TUR	(1,0)	0.30 (0.01)	0.00 (0.00)	1236.8	[-7141, 9614]	(1,0)	-0.28 (0.01)	0.10 (0.00)	17.3‡	[9.1, 25.5]
U.S.	(4,0)	-0.85 (0.01)	1.43 (0.02)	3.6‡	[3.2, 4.0]	(1,0)	-0.43 (0.00)	1.18 (0.00)	2.2‡	[1.6, 2.8]

Note: Regression equation is

$$RPV_t = \alpha_0 + \sum_{h=1}^{p} \alpha_h RPV_{t-h} + \beta_1 \pi_t + \beta_2 \pi_t^2 + \sum_{j=1}^{q} \gamma_j \pi_{t-j} + \varepsilon_t,$$

where the lag lengths (p,q) are selected by the BIC rule. Break points are IT adoption date for ITers and structural breakpoints of inflation for non-ITers. $\hat{\pi}^*$ is the *annualized* monthly inflation rate, obtained from $\hat{\pi}^* = \left(\frac{-\hat{\beta}_1}{2\hat{\beta}_2}\right) \times 12$. 5% and 95% inside the squared bracket represent the lower and upper bounds of the 95% confidence interval of $\hat{\pi}^*$ which is calculated using the delta method. ‡represents that $H_0 : \pi^* = 0$ can be rejected at 5%. The numerical inflation targets are obtained from the IMF's *Monetary Bulletin* (2007-2) and central banks' websites.

Figure captions

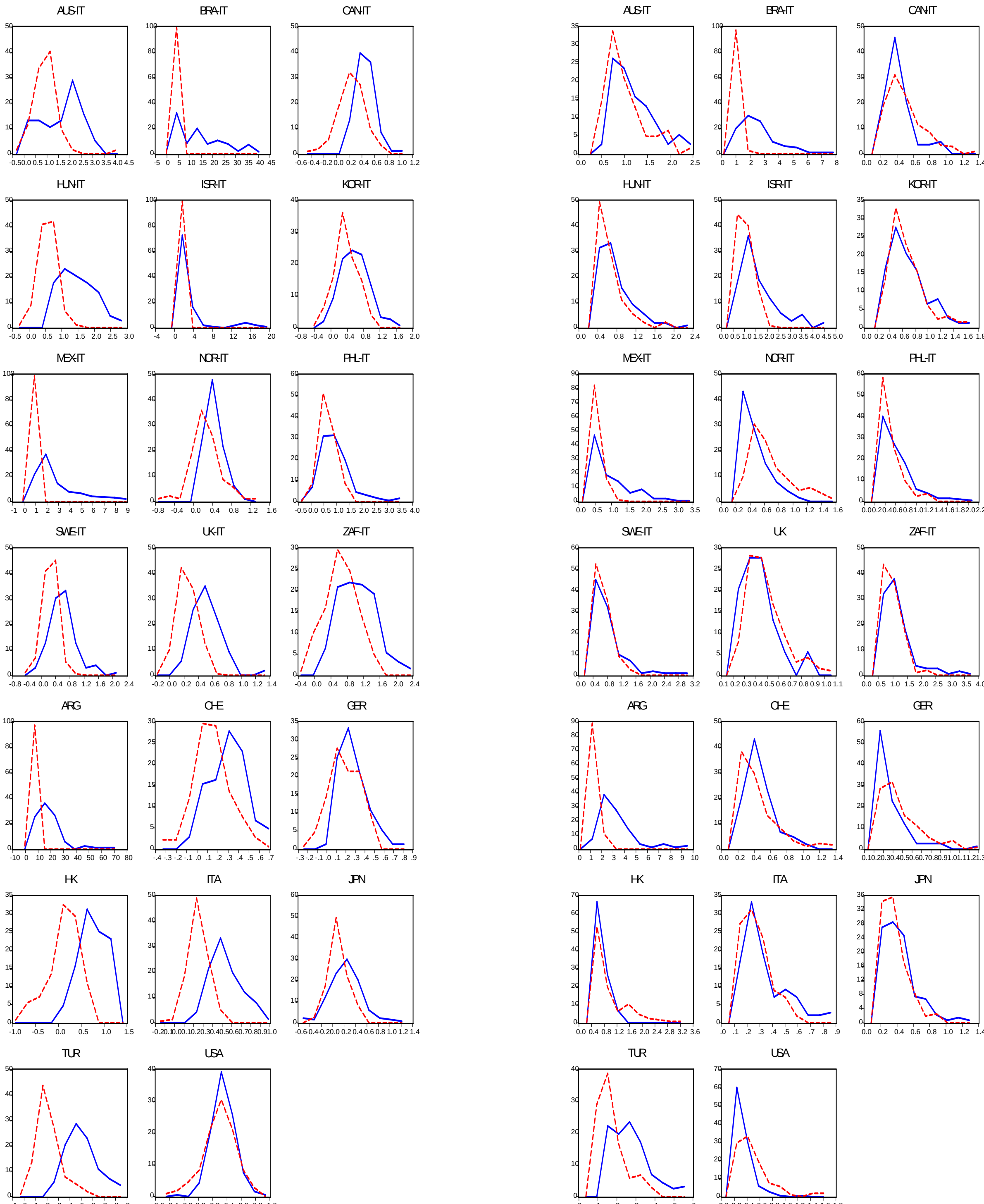
Figure 1: Empirical densities of inflation and RPV before (solid line) and after (dotted line) break points

Figure 2: Nonparametric estimates of $g'(\cdot)$ function for different values of inflation (π_t)

Figure 3: Rolling 10-year estimates of marginal effects of inflation (β_1: thin line) and inflation volatility (β_2: heavy line) on RPV

Figure 4: $\hat{\pi}^*$ (thin line), long-run inflation expectations (heavy line), and the period average inflation rate (dotted line) in the U.S.

Figure 5: Rolling 10-year estimates of π^* (heavy solid line) with period average inflation rates (dotted line) and targeted inflation range (thin solid line)



Panel A: Inflation Panel B: RPV

Figure 1: Empirical densities of inflation and RPV before (solid line) and after (dotted line) break points

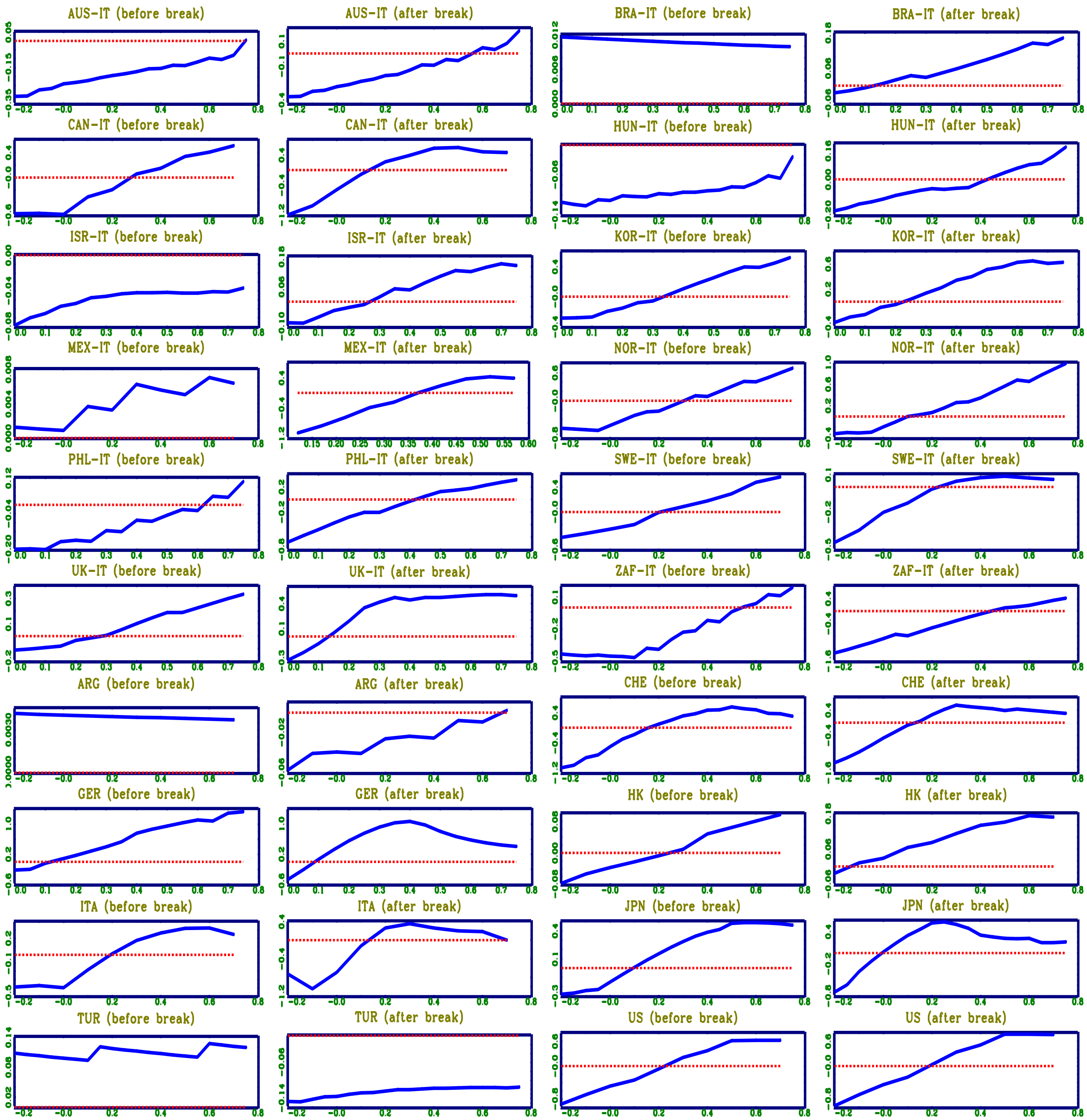


Figure 2: Nonparametric estimates of $g'(\cdot)$ function for different values of inflation (π_t)

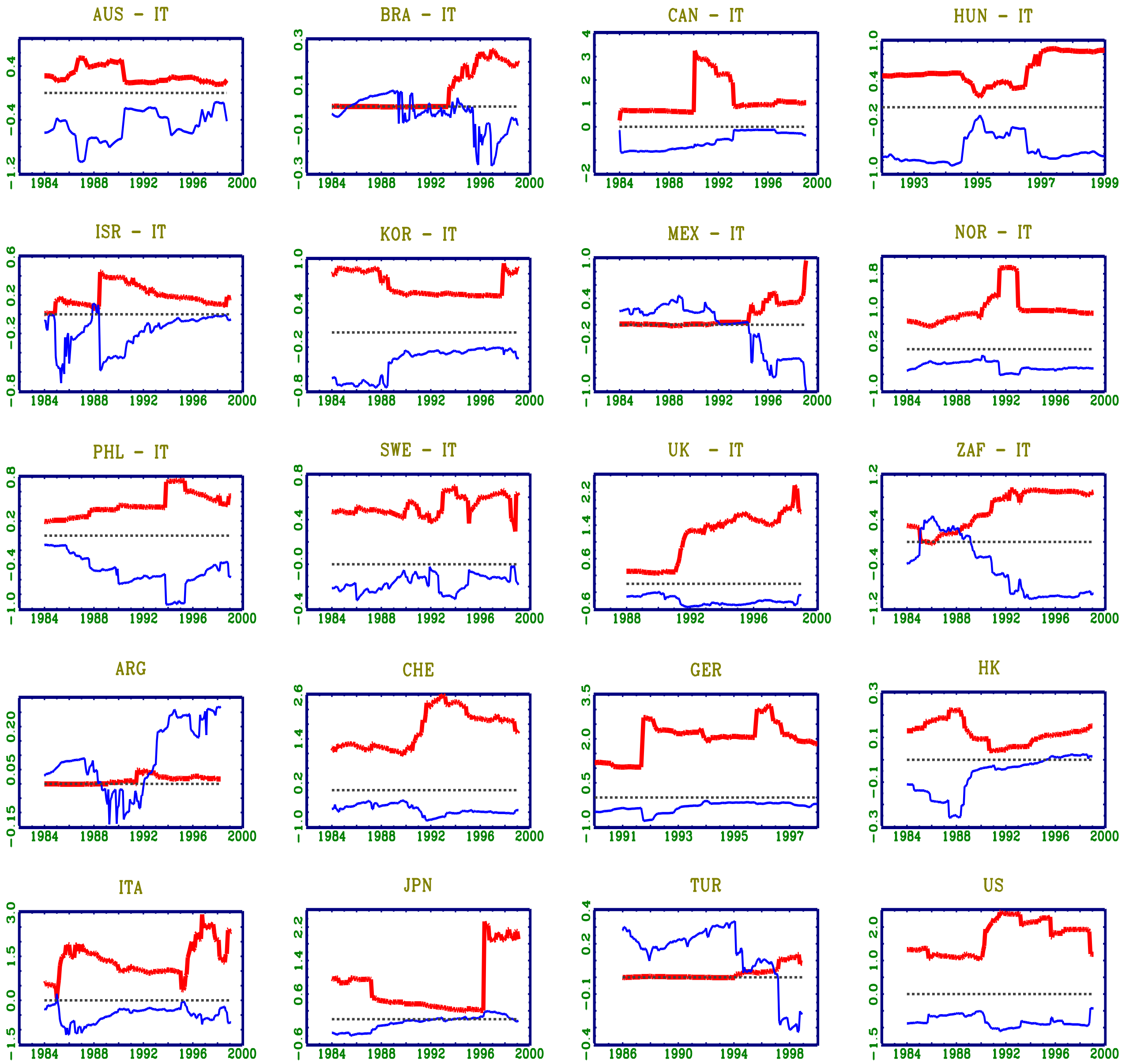


Figure 3: Rolling 10-year estimates of marginal effects of inflation (β_1: thin line) and inflation volatility (β_2: heavy line) on RPV

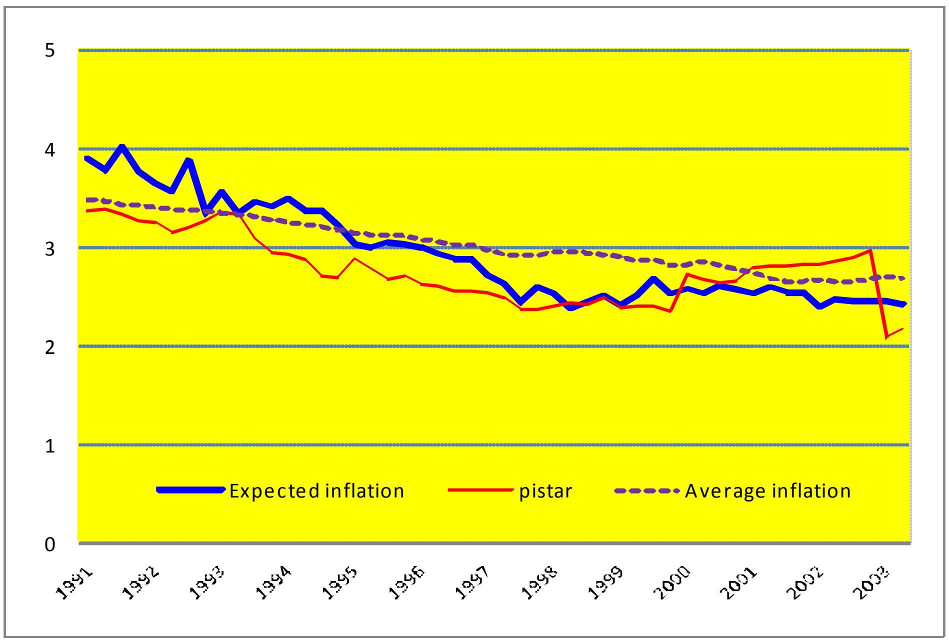


Figure 4: $\hat{\pi}^*$ (thin line), long-run inflation expectations (heavy line), and the period average inflation rate (dotted line) in the U.S.

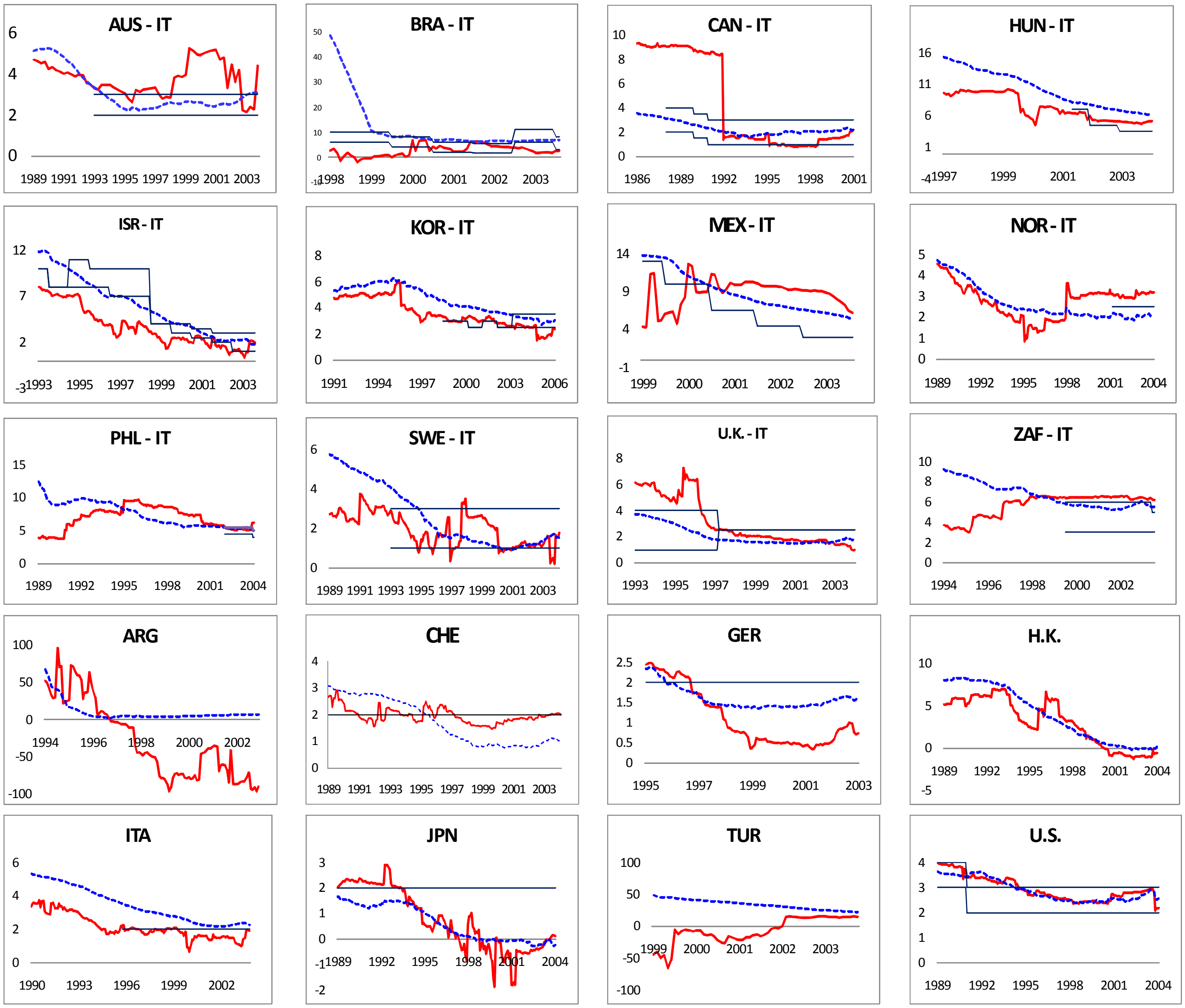


Figure 5: Rolling 10-year estimates of π^* (heavy solid line) with period average inflation rates (dotted line) and targeted inflation range (thin solid line)

Appendix: Data Description

Table A.1: Data Description

Country	Data span	Data source	Subaggregate Items
AUS	1984:Q1-2009:Q1 {1993:Q2}	Australian Bureau of Statistics (ABS)	[8] food (20.7); alcohol and tobacco (9.2); clothing and footwear (5.2); housing (26.2); household contents and services (12.9); transportation (17.6); communication (4.4); education (3.6)
BRA	1984:M1-2009:M2 {1999:M6}	Brazilian Institute of Geography and Statistics (IBGE)	[7] food products and beverages (23.6); housing (16.7); household articles (6.4); apparel (8.4); transportation and communication (20.1); health and personal care (10.3); personal expenses (14.6)
CAN	1984:M1-2009:M2 {1991:M2}	Statistics Canada	[8] food (17.0); shelter (26.6); household operations and furnishings (11.1); clothing and footwear (5.4); transportation (19.9); health and personal care (4.7); recreation, education and reading (12.2); alcoholic beverages and tobacco products (3.1)
HUN	1992:M1-2009:M2 {2001:M6}	Hungarian Central Statistical Office (KSH)	[7] food (23.7); alcoholic beverages and tobacco (9.6); clothing and footwear (5.6); consumer durable goods (7.3); electric gas and other fuels (8.5); other goods including motor fuels and lubricants (16.8); services (28.5)
ISR	1984:M1-2009:M2 {1997:M6}	Central Bureau of Statistics	[10] food, excluding vegetables and fruit (14.8); vegetables and fruit (3.6); housing (20.7); dwellings maintenance (10.6); furniture and household equipment (3.8); clothing and footwear (3.2); health (5.2); education, culture and entertainment (12.5); transport and communication (21.1); miscellaneous (4.5)
KOR	1984:M1-2009:M2 {1998:M4}	Korea National Statistical office (NSO)	[12] food and non-alcoholic beverages (14.0); alcoholic beverages and cigarettes (1.5); clothing and footwear (5.8); housing, water and fuels (17.0); furnishings and household equipment (4.2); health (5.2); transportation (10.9); communication (6.0); culture and Recreation (5.6); education (11.1); eating-out and accommodation (13.3); miscellaneous (5.4)
MEX	1984:M1-2009:M2 {2001:M1}	Bank of Mexico	[8] food, beverages and tobacco (22.7); clothes, footwear and accessories (5.6); housing (26.4); furniture and domestic accessories (4.9); health and personal care (8.6); transportation (13.4); education and entertainment (11.5); miscellaneous (6.9)
NOR	1984:M1-2009:M2 {2001:M3}	Statistics Norway	[12] food and non-alcoholic beverages (11.2); alcoholic beverages and tobacco (2.7); clothing and footwear (5.9); housing, water, electricity, gas and other fuels (29.5); furnishings, household equipment and routine maintenance (6.3); health (2.7); transport (17.9); communications (2.1); recreation and culture (12.0); education (0.3); restaurants and hotels (3.4); miscellaneous goods and services (6.0)
PHL	1984:M1-2009:M2 {2002:M1}	Philippines National Statistical Office	[6] food, beverages and tobacco (50.0); clothing (3.0); housing and repairs (16.8); fuel,light and water (6.9); services (15.9); miscellaneous (7.3)
SWE	1984:M1-2009:M2 {1993:M1}	Statistics Sweden	[11] food and non-alcoholic beverages (13.2); alcoholic beverages and tobacco (3.7); clothing and footwear (5.4); housing, water, electricity, gas and other fuels (26.7); furnishings and household goods (5.5); health (3.2); transport (14.6); communication (3.5); recreation and culture (11.9); restaurants and hotels (6.8); miscellaneous goods and services (5.4)
U.K.	1988:M1-2009:M2 {1992:M10}	National Statistics	[12] food and non-alcoholic beverages (11.8); clothing and footwear (5.7); alcoholic beverages,tobacco and narcotics (4.4); housing, water and fuels (12.6); furnishings, household equipment and routine repair of house (6.6); health (2.2); transport (15.1); communication (2.3); recreation and culture (14.5); education (2.1); hotels, cafes and restaurants (12.8); miscellaneous goods and services (9.9)

ZAF	1984:M1-2009:M2 {2000:M2}	Statistics South Africa	[17] food (21.0); non-alcoholic beverages (1.1); alcoholic beverages (1.4); cigarettes, cigars and tobacco (1.1); clothing and footwear (3.3); housing (22.1); fuel and power (3.5); furniture and equipment (2.5); household operation (4.8); medical care and health expenses (7.2); transport (14.8); communication (3.0); recreation and entertainment (3.3); reading matter (0.4); education (3.5); personal care (3.7); other (3.3)
ARG	1984:M1-2009:M2 {1991:M4}	National institute of Statistic and Censuses (INDEC)	[9] foods and beverages (31.3); apparel (5.2); housing and basic services (12.7); household equipment and maintenance (6.5); medical attention and health-care expenses (10.0); transportation and communication (17.0); leisure (8.7); education (4.2); miscellaneous goods and services (4.4)
CHE	1984:M1-2009:M2 {1993:M6}	Federal Statistical Office	[12] food and non-alcoholic beverages (10.9); alcoholic beverages and tobacco (1.7); clothing and footwear (4.2); housing and energy (19.7); furnishings, household equipment and routine household maintenance (4.6); health (14.3); transport (11.0); communication (2.8); recreation and culture (10.9); education (0.9); restaurants and hotels (9.8); miscellaneous (10.2)
GER	1991:M1-2009:M2 {1992:M10}	Federal Statistical Office Germany	[12] food and non-alcoholic beverages (10.4); alcoholic beverages and tobacco (3.9); clothing and footwear (4.9); housing, water, electricity, gas and other fuels (30.8); furnishings and household equipment (5.6); health (4.0); transport (13.2); communication (3.1); recreation and culture (11.6); education (0.7); restaurants and hotels (4.4); miscellaneous goods and services (7.4)
H.K.	1984:M1-2009:M2 {1997:M3}	Census and Statistics Department	[9] food (26.9); housing (29.2); electricity, gas, and water (3.6); alcoholic drink and tobacco (0.9); clothing and footwear (5.9); durable goods (5.5); miscellaneous goods (4.8); transport (9.1); miscellaneous services (16.2)
ITA	1984:M1-2009:M2 {1995:M11}	National institute of Statistics	[8] food, beverages, and tobacco (21.8); clothing and footwear (9.7); housing, water, electricity, gas and other fuels (11.0); furnishings and household equipment (9.7); health (9.0); transport and communication (20.2); education, recreation, and culture (9.8); miscellaneous (9.0)
JPN	1984:M1-2009:M2 {1993:M8}	Statistics Bureau	[10] food (24.6); housing (26.3); fuel, light, and water charge (5.8); furniture and household utensils (2.9); clothes and footwear (4.9); medical care (4.1); transportation and communication (10.2); education (4.7); reading and recreation (11.1); miscellaneous (5.5)
TUR	1986:M1-2009:M2 {2002:M3}	Central Bank of the Republic of Turkey (CBRT)	[5] foodstuffs (36.6); heating and lighting articles (9.8); clothing and house furniture (9.4); house rent and maintenance (11.7); miscellaneous (36.4)
U.S.	1984:M1-2009:M2 {1999:M9}	Bureau of Labor Statistics (BLS)	[6] apparel (4.2); food (17.9); other (3.8); housing (49.4); medical (7.3); transportation (17.4)

Note: Dates in { } refer to the IT adoption date for targeters and the break point of the inflation series estimated by the Bai-Perron (1998) method for nontargeters. The numbers in brackets represent the number of subaggregates and the entries inside the parenthesis denote the weight of each subaggregate.