Inflation has been low in many countries for at least a decade. But have inflation processes changed in ways that would help make low inflation permanent? Using both aggregate and disaggregated inflation data, we find that the means of inflation processes have become smaller over the past two decades and that, allowing for these changes in the mean, their persistence has not declined much. Changes in monetary policy frameworks and recessions appear to have contributed to a reduction in the mean of inflation, but do not appear to have a meaningful impact on persistence, and there is some evidence that the shifts in inflation expectations are the proximate cause of the changes in the mean of inflation. These findings suggest that policy-makers should focus on maintaining credibility and carefully monitoring inflation expectations for any indication that they are rising.

— Stephen G. Cecchetti and Guy Debelle
Has the inflation process changed?

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1. INTRODUCTION

Low inflation has been a fact of economic life in many countries now for at least a decade. While some have had low inflation since the early 1980s (at least), the 1990s was notable for the widespread incidence of low inflation, including among a large number of formerly high inflation economies in Latin America and Eastern Europe.

On a number of occasions, the advent of low inflation has coincided with changes in the monetary policy framework, which in many cases has involved the adoption of a form of inflation targeting. But in other countries, there has been no marked change in the policy regime. This raises the important question of whether the nature of the inflation process has changed in a manner which has helped entrench low inflation.

One means by which this could occur would be if the inflation process has become less persistent; that is, a given shock to the price level which boosts inflation now has

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a smaller and/or less protracted impact on the rate of ongoing inflation. If the inflation process is less persistent, the task of monetary policy is easier. The sacrifice ratio (that is, the cost of reducing inflation in terms of lost output) will be lower. Moreover, with low inflation persistence and a flexible inflation target, inflation may simply fluctuate around the desired target level with little action required from the policy-maker.

If inflation persistence has declined, why has it occurred? One possible explanation is that the decline in persistence itself is related to a change in the conduct of monetary policy. Taylor (1998, 2000) makes this general argument while Sargent (1999) provides a detailed account of the interaction between inflation persistence and the monetary framework in the United States. The case centres on the observation that over the past decade or so, monetary policy has been much more focused on achieving low inflation, and less on exploiting short-run output gains. These policies have been successful, leading to an increase in the credibility of monetary policy. Increased credibility has, in turn, anchored inflation expectations at a low (and constant) rate of inflation – at the inflation target in those countries which have such a formal target. The dramatic consequence is that inflation expectations are unlikely to adjust to temporary increases in inflation. This reduces the persistence of shocks to both the price level and inflation.

The fact that empirical researchers find substantial persistence in inflation data has posed a challenge for macroeconomic theorists. As Fuhrer and Moore (1995) first noted, modern models of aggregate fluctuations based on price rigidity imply that inflation should not be positively serially correlated. There are several possible explanations for this inconsistency including that the persistence in inflation arises from backward-looking behaviour on the part of price setters or from persistence in the real shocks hitting the economy.

In this paper we address these questions by studying the univariate inflation process in a number of countries. Levin and Piger (2003) and Gadzinski and Orlandi (2004) conduct a similar exercise. In contrast to their analysis, however, we examine not only the consumer price index (CPI) in aggregate, but also its components. This helps us to identify if changes in the inflation process have a common source. For example, if inflation persistence is lower because of increased credibility in the monetary policy framework and the consequent anchoring of inflation expectations, one should see a similar reduction in persistence in all components of the CPI.

While from a monetary policy perspective, aggregate inflation behaviour is probably most relevant, the disaggregated data may reveal some useful insights about the nature of the price-setting process. The disaggregated data may indicate that the level of and changes in persistence are solely attributable to persistence in inflation in a few segments of the economy. Analysis of the disaggregated data may also reveal whether the observed persistence (or lack thereof) may be influenced by the statistical methodology

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1 See also Anderton (1997).
employed in calculating the CPI. More generally, understanding the source of the change in the inflation process may allow one to make an assessment of how long-lasting such a change may be. The use of disaggregated cross-country price data also allows us to test whether various theories of price setting are consistent with what we see in the data.

A similar approach has been undertaken simultaneously by Ernst and Mojon (2004), focusing on euro area countries. We use a wider sample of countries than they do, encompassing a larger number of monetary policy regimes, and changes to those regimes. Furthermore, we allow for there to be more structural breaks (up to three rather than just one) and for the timing of those shifts to be chosen by the individual inflation data (rather than all be restricted to occur at the same time).

The analysis in this paper focuses on identifying changes in the inflation process attributable to changes in both the mean and the persistence of inflation, as well as the interaction between the two. As other authors observe, there is an important relationship between the mean and persistence of an economic time series. Much of the work analyses the inflation process (see Perron, 1989; and Levin and Piger, 2003). We show that after allowing for changes in the mean of inflation (normally one mean break is sufficient over our sample), inflation has generally not had a particularly high level of persistence, similar to the results in Levin and Piger (2003) and Gadzinski and Orlandi (2004). Importantly, this result suggests that measures of inflation persistence that have been obtained previously depend crucially on the sample period over which they are calculated. These results are common across all categories of prices that we examine. After allowing for the change in the mean of inflation, we do find some evidence of a decline in persistence in the recent period, but the order of magnitude of this decline is less than that found previously in the literature.

Thus our primary conclusion is that the principal change in the inflation process over the past two decades has (not surprisingly) been the decline in the mean. The decline in the persistence of the process has generally been of second order importance, and in some cases has been trivial. Hence the common view that inflation persistence is high is not supported by our results.

Our results suggest that the focus of analysis of the inflation process should be on the causes of the changes in its mean. They show that the timing of the decline in the mean of the inflation process is often difficult to link directly to marked changes in monetary policy frameworks. In several countries, there is some evidence of a simultaneous decline in mean across the different components of inflation that coincides with a change in the policy framework, but often these also coincide with a recession or marked slowdown in growth, so it is difficult to disentangle these two influences without looking at additional information on the sources of variation in inflation. In principle, this would include a host of potential determinants of inflation’s long-run trends and short-run fluctuations, including such things as changes in marginal cost and the markup.

With this in mind, we examine the proposition that the shifts in inflation expectations are the proximate cause of the changes in the mean of inflation, and we present
some evidence which supports this proposition. Reducing inflation expectations from a high level is inherently costly. Once inflation expectations are reduced, however, the intrinsically low persistence of inflation should ensure that a low inflation regime is maintained. The focus of policy-makers, therefore, should be on maintaining the credibility of the regime and carefully monitoring inflation expectations for any indication that they are rising.

Our study of the disaggregated data shows that while many sectors of the economy have very low levels of persistence, there are a few sectors, most notably housing, where higher levels of persistence can remain even after allowing for shifts in the mean. As Altissimo et al. (2004) demonstrate, aggregate series inherit the persistence of their most persistent component. This proposition is demonstrated in our results.

This allows us to comment on the debate over the appropriate monetary policy target. Mankiw and Reis (2002) and Benigno (2004) both point out that welfare considerations suggest weighting regional and sector inflation not by their economic size but by their degree of nominal rigidity – sectors and regions with higher rigidity should receive higher weight.\footnote{Political economy arguments militate against this, as such a policy runs the risk of rewarding industries and regions that fail to implement structural adjustments that would reduce such rigidities.} The simple intuition is that the more sluggish is nominal adjustment, the larger the real adjustments are. Since policy-makers are concerned with minimizing the latter, as they are what create welfare losses, they should seek to stabilize the sectors where these are biggest. However, we show that the time-series properties of the data naturally treat the persistence of inflation in the various sectors and regions in the manner the theory suggests they should. The implication is that by stabilizing aggregate inflation, policy-makers will stabilize inflation of the persistent components. While Mankiw and Reis (2002) and Benigno (2004) may be right in theory, in practice there is no need for policy-makers to do anything as complex as they suggest.

Our results also raise questions about the mapping of various theories of price determination to movements in aggregate inflation. The previous literature argues that the finding of high levels of persistence is inconsistent with most of the standard theories. Our finding of low inflation persistence is thus more supportive of these theories. When we examine the link between our estimates of persistence for the disaggregated CPI data, and estimates obtained from other studies of the duration of price-setting, the results obtained are still at odds with conventional price theories. Finally, our analysis also reveals that in some cases, statistical methodology for calculating the CPI can influence the time series properties of the data.

2. THEORETICAL MOTIVATION

Theories of aggregate inflation persistence have generally been derived from microeconomic models of price setting that can be classified into three broad categories
(and which need not be mutually exclusive): time-dependent models, limited information models and menu-cost or state-dependent models. Many of these models imply high persistence in the price level, which then translates into very low or even negative persistence in inflation.

The canonical time-dependent model of price-setting was developed by Taylor (1980). In Taylor’s model, prices are set as a mark-up over marginal cost in a sequence of overlapping wage contracts which last for a fixed number of periods, $n$. Each contract is set to take account of both the wages in existing contracts and the wages expected to be set in future contracts. At any point in time, the aggregate price level is the average of the level of prices over the past $n$ periods. In this set-up, shocks today affect wages, and hence the price level, for the next $n - 1$ periods, as each of the $n$ contracts is renegotiated. The longer the length of the contract, the more persistent will be the effect of shocks on wages and on the price level. However, positive persistence in the price level implies negative persistence in the rate of inflation. Fundamentally then, the Taylor model is one of price level persistence rather than inflation persistence.

Similarly the much used model of Calvo (1983) implies positive persistence in the price level, but no persistence in inflation. In this model, firms change their prices in response to a signal they receive with a fixed probability each period. When prices change, firms reset them to minimize deviations from the expected optimal price level. Because only a subset of prices is changed each period, changes are staggered. The timing of the changes generates the persistence in the price level in response to a shock. But since the price setters are forward looking, basing their decisions in part on expectations, the result is that inflation has no persistence. Instead inflation moves immediately to its new level in response to a shock.

These models of overlapping contracts have been criticized for their assumption of an exogenous fixed contract length (and fixed probability of receiving a signal). An alternative strategy is to assume state-dependent price setting, such as that implied by menu-cost models, where prices are changed depending on the state of the economy and the gap between the current price and the desired price level. Caplin and Spulber (1987) show that standard menu-cost based models of price adjustment do not generate a straightforward mapping between individual price changes and the behaviour of the aggregate price level. Indeed the relationship can vary considerably over time, depending on the shocks that precipitate the price changes. As a result, the persistence of the price level depends on the size and timing of the shocks, and has no direct implications for inflation persistence.

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1 Taylor (1999) provides a comprehensive survey of the literature.

2 Take the simple case in which $\rho_t = \rho \rho_{t-1} + \varepsilon_t$, where $\rho_t$ is the log of the price level, $\rho$ is a coefficient, and $\varepsilon_t$ is a white noise disturbance. If one estimates an AR(1) on the first difference of $\rho_t$, the resulting autocorrelation estimate will be $\frac{1}{2} (\rho - 1)$. So, for the cases in which the price level has positive persistence, inflation will have negative autocorrelation. A general $n$ period model will yield a high-order autoregressive process. In all cases, persistence in the price level will depend not only on the length of the contracts, but also on things like the relative-price elasticity of demand. Whelan (2004) demonstrates this in a more general context.
Limited information models generate some persistence in both the price level and inflation. The Lucas (1972) islands model of price setting is the basis for models of this genre. In the face of increased demand for her product, a price-setter is unsure whether this reflects general upward pressure on prices or an idiosyncratic shock. This creates a signal extraction problem where individuals have to ascertain the extent to which the observed price change is economy wide or firm specific. Price setters will only gradually adjust their prices upwards as the information problem is resolved. The limited information slows down the price adjustment process inducing some persistence in aggregate inflation as price setters learn what the true signal is.

Variants of the Calvo and Taylor time-dependent price-setting models are a central part of many New Keynesian models (for example, Woodford, 2003). In these models, persistence in inflation can be attributed to four sources: the price-setting process (along the lines of the models discussed above); the mark-up of prices over marginal cost which in turn is related to persistence in the output gap; inflation expectations; and other shocks to the inflation process itself.

As discussed above, the price-setting process itself is unlikely to be a source of positive persistence – indeed the opposite may be true. With forward-looking behaviour, persistence will be zero.

Persistence in the mark-up is related to persistence in the output gap. However, while monetary policy can contribute to some reduction in persistence from this source, the inherent persistence in economic activity provides a lower bound to this.

In many New Keynesian models, the assumption of forward-looking inflation expectations implies that aggregate inflation has no persistence. This aspect of these models has been criticized by, inter alia, Ball (1994), Fuhrer and Moore (1995) and Rudd and Whelan (2001). Ball (1994) pointed out that traditional time-dependent models imply that (credible) disinflations are costless, and, in some cases, can even be associated with a boom in output. This is clearly at odds with the practical experience.

The inflation expectations process is therefore the likely source of inflation persistence. Fuhrer and Moore develop a framework where inflation expectations can be written as a weighted average of backward and forward-looking inflation expectations, where the backward-looking component is simply lagged inflation. Fuhrer (2005) confirms that backward-looking expectations formation is the most likely source for observed inflation persistence in the US. (Allowing for a backward-looking component in expectations formation has been a common approach in modelling inflation in applied policy research.)

The influence of the monetary policy framework, and particularly an announced inflation target, on the inflation process can then be modelled in terms of their influence on the degree to which inflation expectations are forward looking. A perfectly credible inflation target would cause all price setters to adopt completely forward-looking inflation expectations, anchored on the inflation target, resulting in a world very similar to that in most New Keynesian models. The announcement of
a credible inflation target would thereby lead to a marked decline in inflation persistence from the previous regime where there was a strong backward-looking element to expectations (Taylor, 1998).

Erceg and Levin (2003) and Orphanides and Williams (2003) develop models of this sort. They show that inflation persistence can come from the public’s limited information about the central bank’s policy objectives. The persistence arises because the public only gradually learns about changes in the central bank’s policy framework. When there is no change in the framework, or the framework is credible, inflation persistence should be low. Similarly Orphanides and Williams simulate a model with similar features and show that the absence of a long-run inflation objective for the central bank results in markedly higher inflation persistence than a world where the inflation objective is clearly understood by price-setters.\(^5\)

Using an analogous argument, Sargent (1999) links inflation persistence directly to the central bank’s understanding of the inflation process and its monetary framework (see also Cogley and Sargent, 2001). He argues that the inflation of the late 1960s and early 1970s resulted from the adoption of an inappropriate monetary framework by the Federal Reserve (a similar argument can be made for other countries). The Federal Reserve misinterpreted the evidence of low inflation persistence in the 1950s and 1960s as implying an exploitable trade-off between inflation and output. The objectives of the central bank did not change, rather their understanding of the economy was incorrect.

Effectively, inflation models failed to take account of the fact that inflation expectations may be sensitive to the level of inflation itself, so that when inflation rose, expectations of future inflation rose as well. Over time, following the rise in inflation that resulted from this mistaken approach, the Fed gradually learned the true process for inflation. Policy-makers observed the persistence in aggregate inflation as expectations adjusted upwards. Their monetary policy framework changed to take account of the inflation persistence, and policy was once again directed at reinstating low inflation, through the disinflations of Volcker and Greenspan. Sargent expresses the concern that the low persistence being observed today may cause central banks to mistakenly try to exploit a traditional Phillips Curve trade-off, thinking incorrectly that the inflationary consequences of a rise in inflation induced by an increase in output will be minor.

Most of these theories of price-setting assume a seamless mapping from the firm-level price-setting decision to aggregate inflation. However, aggregation issues may be

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\(^5\) The argument can be illustrated very simply with a basic Phillips curve inflation equation where expectations are a mixture of backward and forward expectations and where the forward component is the inflation target, $\pi$. Write the standard Phillips curve as $\pi_t = \pi_t^* + \beta(\pi_t - \bar{\pi}) + \epsilon_t$, and define expectations by $\pi_t^* = \alpha \pi_{t-1}^* + (1 - \alpha)\pi_t$. The persistence of the inflation process is given by the parameter, $\alpha$, the weight on the backward-looking term in the equation for inflation expectations. As the weight on the inflation target increases, $\alpha$ declines and observed inflation persistence declines, until in the limit, with perfect credibility of the inflation target, $\alpha = 0$ and there is no persistence in the univariate inflation process (except to the extent that the output gap term is autocorrelated).
critical. That is, it is possible that there is an important difference between thinking about inflation as though there was only one good in the economy rather than the reality that the consumer price index is an amalgam of many different prices. Hence is it meaningful to talk about persistence in aggregate inflation versus persistence in the components? In terms of Lucas’s island model, one can think of all prices rising through time with a common component given by the inflation target and relative price movements around that common mean. There may well be persistence in the individual goods categories, as a result of staggered price changes by individual producers of each good in response to a shock to that particular good, but this would not necessarily translate into inflation persistence in the aggregate inflation process, where the effect of the common stable mean would tend to dominate. Alternatively, as discussed above, Caplin and Spulber (1987) and Caplin and Leahy (1997) show that the relationship between individual behaviour and the aggregate price data can be quite imprecise.

3. METHODOLOGY

Estimates of persistence have been obtained in univariate models of inflation, models of the Phillips curve which also take account of the influence of the output gap, exchange rate changes and oil prices on inflation, as well as in larger macroeconomic models. Box 1 summarizes the existing empirical literature on inflation persistence.

Box 1. Existing evidence on inflation persistence

Much of the previous literature has tended to find that the inflation process is highly persistent. The AR coefficient is often close to one in a large number of countries when estimated on inflation data over the past twenty years or so (Clark, 2003; Gadzinski and Orlandi, 2004; Levin and Piger, 2003; Batini, 2002; Batini and Nelson, 2001; O’Reilly and Whelan, 2004; Stock, 2001). This is the stylized fact which has motivated much of the subsequent theoretical work.

More recently, some papers have examined whether this estimate of persistence has changed over time. Debelle and Wilkinson (2002), Levin and Piger (2003) and O’Reilly and Whelan (2004) used rolling regressions to examine the evolution of the AR coefficient. Debelle and Wilkinson show that persistence has declined considerably over the past decade in Australia, the United Kingdom, Canada and New Zealand, but there was little evidence of a decline in persistence in the United States. Using more recent data Levin and Piger show that in the United States, persistence has also declined by a similar order of magnitude, but only relatively recently. O’Reilly and Whelan (2004) and
Gadzinski and Orlandi (2004) find little evidence of a change in persistence in euro area countries. These rolling regressions can indicate whether persistence has changed, but are not very precise in determining the exact timing of the change in persistence and hence it is difficult to map the change in persistence to factors such as a change in the monetary policy framework.

Clark (2003) and Levin and Piger (2003) allow for an explicit shift in the mean of the inflation process, and demonstrate that, even so, inflation persistence is markedly lower in the more recent period. For example, Clark finds that allowing for a break in the mean of inflation in 1993Q1, inflation persistence in the United States in an AR model is reduced substantially from roughly 0.9 to 0.13. Similarly, the results in Levin and Piger show that once a structural break is allowed for, the null hypothesis of a unit root can be rejected at the 95% confidence level for 29 of the 48 inflation series that they examined, whereas the null hypothesis could only be rejected for eight series when no structural break was allowed for. Gadzinski and Orlandi (2004) also find that once shifts in the mean are controlled for, persistence has generally been low in euro area countries and the United States. Bilke (2004) and Corvoisier and Mojon (2005) show that persistence in aggregate measures of inflation in France and OECD countries (respectively) has been low for a number of decades once mean breaks are allowed for. Bilke finds evidence of only a single mean break in France in the mid 1980s, while Corvoisier and Mojon find a number of significant breaks in OECD countries over the past four decades: in the late 1960s/early 1970s, the early-mid 1980s and the early 1990s.

Other authors have examined inflation persistence at a very disaggregated level, using the price data that are the basic inputs to the CPI. Bils and Klenow (2002) examine the properties of 123 price components of the US CPI. They find that few of these series exhibit much persistence; and that there is little relationship between the frequency of price change and what persistence (and volatility) there is in the price series. Clark (2003) uses a similar data set and finds that again, after controlling for a structural shift in the mean, there is very little evidence of persistence in either the aggregated or disaggregated data. In Europe, Angeloni et al. (2005) use micro data to determine whether European monetary union had an effect on inflation persistence and find little evidence that it did but present some evidence of a decline in persistence in the mid-1990s. Aucrémanne and Dyhne (2004) examine disaggregated data for Belgium, while Álvarez and Hernando (2004) use Spanish data to determine whether time- or state-dependent models best describe pricing behaviour. The former find that a mix of both models appears to be present in the data, while the latter find evidence in support of the Calvo model. But as the discussion in Section 2 shows, this is consistent with zero persistence in inflation.
Our use of a univariate model means that we are omitting other potential drivers of the inflation process. This omitted variable bias may influence our estimates of persistence in a way that does not allow us to identify its source. For example, as described above, in a New Keynesian model, a portion of the persistence in the inflation process may derive from the process determining the output gap. Again, however, the purpose of this exercise is primarily to document the statistical properties of the inflation process. We are interested in the following questions: Is the inflation process persistent? And, has that persistence declined? If the answer to the first question is yes, then it would be useful to identify the source of that persistence from a more fully specified model.\footnote{Our strategy is supported by the results in Fuhrer (2005) who concludes that, to the extent that inflation is persistent, the forcing process is not the likely source.}

A number of approaches have been used in the literature to measure persistence in a univariate model of inflation. These have included the coefficient on the lagged dependent variable in an inflation equation, the sum of the lagged coefficients in an AR($n$) model of inflation, the half-life of a shock to the inflation process and the number of times the inflation process crosses its mean \citep[see][]{AndrewsChen:1994,RobaloMarques:2004} for a discussion of these issues). Overall, these measures give broadly similar estimates of inflation persistence \citep{Clark:2003}. In this paper we use a measure calculated as the sum of the coefficients of an AR(12) process for monthly price series and an AR(4) process for quarterly price series.\footnote{Hereafter, a reference to an AR(12) model should be translated to AR(4) for Australia and New Zealand which only have quarterly CPI data.}

We have done a full set of exactly analogous computations based on the AR(1) coefficient and, using an alternative measure of persistence, we identify the structural breaks as before, but then calculate the number of times the inflation process crosses its mean, as suggested by Robalo Marques \citeyear{RobaloMarques:2004}. All three measures yield the same results, so we only report the AR(12) results.

If the estimates of persistence are close to one (that is, inflation is close to a unit root process), \citet{Hansen:1999} shows that the point estimates can be biased downwards and provides a bootstrap procedure to calculate the estimates of persistence as well as their confidence intervals. However, as we will show in the next section, many of our estimates are relatively small (in absolute value) and so this is not a major issue.

In obtaining their estimates of high inflation persistence, and measuring the change in persistence over time, very few papers have allowed for the possibility of a shift in the mean of inflation over the sample period. \citet{Perron:1989} shows that failing to account for a shift in the mean of a process will give misleading estimates of persistence. Against this, allowing for too many shifts in the mean can lead to an underestimate of persistence. In the extreme, controlling for a shift in the mean each period would generate an estimate of zero persistence. In this paper we take an agnostic view on the appropriate number of mean shifts to allow for. Our primary purpose is to
demonstrate the significant impact that mean shifts can have on existing estimates of persistence. As will be discussed in the results below, the largest decline in the estimate of persistence tends to occur when only one mean shift is allowed for.

To test for shifts in the mean, we use the methodology described in Bai (1999). First we conduct a Quandt (1960) test on the AR(12) models of inflation. This finds the maximum value of the Chow test over all possible break points. Once we have identified this point, we re-estimate the model allowing for a structural break in the mean at this date and obtain a second estimate of persistence. We then adopt the same procedure to identify a second and third mean break, in each case obtaining another estimate of persistence. Levin and Piger (2003) find that Bayesian methods of testing for structural breaks generate very similar results to the approach we have adopted here.

We also conduct the same Quandt procedure to identify a structural shift in persistence in the original AR(12) regressions with no mean breaks, as well as the regressions which include one break in the mean of the series.

In addition to testing for persistence in the aggregate CPI, which has tended to be the focus of much of the previous literature, we examine the persistence properties of disaggregated components of the CPI (Ernst and Mojon, 2004 adopt a similar approach using euro area data). Along with the use of cross-country data, this allows us to investigate where the changes in the properties of the aggregate CPI series are coming from. If the change in the mean or the persistence parameter is associated with a change in the monetary policy framework, then it is likely that the timing of the change will be similar for the disaggregated components. As a result we have obtained CPI data at the first level of disaggregation, which generally includes the following categories of goods and services: food, alcohol and tobacco, clothing and footwear, housing, furniture, health, transport, recreation, communication and education. An exhaustive search, including contacting researchers at central banks throughout the world, has convinced us that this is all of the consumer price data in existence for the countries we study.

We can also investigate whether the statistical methodology used to calculate the CPI from the raw price data may be artificially generating some of the persistence. For example, the calculation of the housing component of the CPI in some countries involves an estimate of owner’s equivalent rent that embodies a moving average component. And in some countries, the treatment of some prices has changed as the timing of sales changed.

As mentioned above, Altissimo et al. (2004) demonstrate that the aggregate series inherit the persistence of their most persistent component. The argument is summarized in Box 2. Hence, using the disaggregated data we can identify which

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8 Imbs et al. (2005) examine a related problem and note that the relationship between the persistence of the aggregate and the persistence of the components depends on a complex function of the covariances of the time series. For series that are uncorrelated, so the covariances are zero, the persistence of the aggregate is always higher than the weighted average of the persistence of the components (computed using the same weights as those used in constructing the aggregate). This is the case in the example described in Box 2. Even so, to the extent that components share a highly persistent factor, then it is that factor that will dominate the behaviour of the aggregate series.
Box 2. Autocorrelation and aggregation

An aggregate time series inherits its persistence properties from its most disaggregated component. Thinking about averaging a random walk and a white noise series, we can see that this makes sense. Such an average would be a random walk, regardless of the weights.

This example is surely extreme, so it is useful to example a simple experiment within the range of data that we study here. Consider a case in which a time series \( y_t \) is the equally weighted average of two time series \( x_{1t} \) and \( x_{2t} \). That is

\[
y_t = 0.7 x_{1t} + 0.3 x_{2t}
\]

Next, assume that the \( x \)'s are first-order autoregressive processes with different parameters. So

\[
x_{1t} = \rho_1 x_{1t-1} + e_{1t}
\]

\[
x_{2t} = \rho_2 x_{2t-1} + e_{2t}
\]

where \( e_{1t} \) and \( e_{2t} \) are i.i.d. standard normal. Then estimate the AR(1) for \( y_t \)

\[
y_t = \gamma y_{t-1} + u_t
\]

for various values of \( \rho_1 \) and \( \rho_2 \) and compare the estimated value \( \hat{\gamma} \) to the weighted average \( \bar{\rho} = 0.7 \rho_1 + 0.3 \rho_2 \). For the purposes of the experiment, we fix \( \rho_1 = 0.1 \) and vary \( \rho_2 \) from 0 to 0.995. For each parameter setting, we take 1000 draws of time series of length 180 (that is 15 years of monthly data). In every case, the initial conditions are set such that \( x_1 = x_{20} = 0 \) for \( t = -20 \). That is, the first 20 observations are dropped.
The figure plots the median of the estimated value of $\gamma$ obtained from the 1000 draws (the solid line), together with a band equal to plus and minus the mean absolute deviation of the estimates (the light dashed lines), as well as the weighted average $\bar{\rho}$ (the dark dashed line).

The results are quite striking. For $\rho_2$ between 0 and 0.8, the autocorrelation of the average is roughly the average of the autocorrelations. But as $\rho_2$ rises above 0.98, the difference grows rapidly. For $\rho_2 = 0.9$, the autocorrelation of the aggregate is 0.46, well above the average autocorrelation of 0.34. As $\rho_2$ rises to 0.95, the difference becomes even starker: The autocorrelation of the aggregate is 0.580 versus the average of 0.355.

of the components of the CPI are the primary contributors to the persistence in the aggregate CPI, or whether persistence is similar for all components.

Finally, one issue which arises is whether the analysis should be conducted using seasonally adjusted data or data that are not seasonally adjusted. From a theoretical perspective, the non-seasonally adjusted data would be preferable as they relate directly to the actual price decisions taken by the firms. For a number of goods and services such as school fees and clothing, however, there is a large seasonal element to price changes and some price decisions are taken only on an annual basis. This suggests that the seasonally adjusted data will give a more accurate indication of the true underlying inflation process.9

4. RESULTS

The results of our examination of the inflation process fall naturally into three groups. First, there is the set of results based on the aggregate inflation data. Here we have data on 19 countries over various time periods. Second, we present results based on data covering prices in as many as 12 disaggregated categories for each of the countries. Finally, we look at the timing of the changes in the mean of inflation to see if they coincide either within countries or across commodities.

We present the results based on an AR(12) process for inflation estimated with the seasonally adjusted data. Our focus is on the simple sum of the 12 coefficients on the lags in the autoregression. The results obtained with the seasonally unadjusted data were not substantively different, as were the results obtained using the measure of mean-crossings suggested by Robalo Marques (2004).

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9 The data are seasonally adjusted using the X-12 procedure in all cases except for the US and Germany where we were able to obtain seasonally adjusted data directly. The seasonal adjustment is particularly important for some components where there tends to be a large shift in the price level once a year. As we note in the next section, however, all of our conclusions are robust to the use of data that are not seasonally adjusted.
4.1. Aggregate inflation

We begin with an examination of the shifts in the mean of the aggregate inflation series. Table 1 presents results for the first two breaks in the mean. These make clear that the shifts in mean inflation are economically meaningful. The table shows that these changes are often quite large. And in almost 90% of cases the mean break is significant at the 10% level. Focusing on the first break, in a typical case, inflation is around 5 percentage points lower after the break than it was before. The change in the mean after the second break is usually big as well. In some cases, inflation rises after the first break and then falls back after the second; while in others, there is a pattern of continued disinflation. To some extent, these differences reflect the variation in the sample period across countries.

To examine the impact of these large shifts in mean inflation on the inflation process, we start by looking at measures of the persistence in the aggregate inflation series, conditional on allowing for up to three changes in the mean of the series. The results in Table 2 are ordered by the estimate of the persistence that assumes no breaks in the mean of the time series.
Before continuing, it is worth noting an important pitfall of any analysis of this type. If one introduces too many mean breaks, then the estimate of persistence is biased toward zero. It is, therefore, important to be cautious in interpreting the results based on a large number of breaks. We present these primarily as a robustness check.

Turning to the tables, the results have the following noteworthy characteristics. First, without allowing for any changes in the mean, persistence is high – close to 1 in many countries. The exceptions tend to be European countries for which we only have data from the 1990s onwards – an issue to which we return below.

The AR(12) estimates of persistence reported in Table 2 are higher than those obtained using an estimate based on an AR(1) process, although those countries which have higher persistence on the AR(12) measure also tend to have higher persistence on the AR(1) measure. The AR(1) measures were, however, significantly affected by seasonality in the inflation data.

Second, allowing for the mean of inflation to change just once over the sample significantly reduces the estimate of persistence in most countries (the results are shown in Figure 1). Allowing for more changes in the mean further reduces estimated persistence but often by a much smaller amount.
After allowing for one break, ten of the nineteen estimates of persistence exceed one half; allowing for three breaks, only five countries have inflation with persistence larger than one half, namely Belgium, France, Germany, Italy and Japan.

For a number of the European countries reported in Table 2, the results are obtained using data beginning around 1990. In 13 of the countries in our sample, however, we have longer time series (at least for the aggregate CPI series) and are able to examine the importance of the short sample period. For this subset of 13 countries, the results comparing the full sample with a shorter sample beginning in 1990 are reported in Table 3. In each there is a marked decline in measured persistence once we use the shorter sample, although for a number of countries a low level of persistence is only obtained once we allow for one mean break.

Hence if we were to restrict ourselves to the last decade and a half we would conclude that inflation in these countries showed the same lack of persistence evident in the other euro area countries. Alternatively, if we had a longer-run sample for the euro area countries, there may be evidence of higher persistence and/or a higher mean in earlier periods, although Gadzinski and Orlandi (2004) tend not to find this.10

These results highlight the importance of controlling for mean breaks when estimating persistence, as well as the critical role played by the choice of sample period. If one does not allow for any break in the mean, then aggregate inflation persistence tends to be higher and close to one, as has been found previously (e.g., Fuhrer and Moore, 1995; Rudd and Whelan, 2001). However, allowing for even one

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10 Note that we do have a long run of data for the aggregate inflation series for Austria, Belgium, France, Germany, Italy and Spain, but do not have a long time series of the components for any of these countries except Spain.
break in the mean substantially reduces the estimates of persistence, as Levin and Piger (2003) and Gadzinski and Orlandi (2004) have also demonstrated.

If we look for a break in the estimate of persistence without allowing for a break in the mean, we find a decline in persistence in a number of countries. The two exceptions are the Netherlands and Luxembourg where persistence rises in the second half of the sample from a low or negative number. These results (shown in Figure 2) are consistent with those obtained from rolling regressions such as in Debelle and Wilkinson (2002) and Levin and Piger (2003). While inflation persistence declines in nearly every case, the decline is only significant for 12 of the 19 countries. Again, account must be taken of the fact that we only have a relatively recent sample of data for the euro area countries.

Table 3. Impact of sample period on estimated persistence

<table>
<thead>
<tr>
<th></th>
<th>Sample</th>
<th>No breaks</th>
<th>One break</th>
<th>Two breaks</th>
<th>Three breaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Long</td>
<td>0.86</td>
<td>0.59</td>
<td>0.55</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.29</td>
<td>0.13</td>
<td>−0.06</td>
<td>−0.18</td>
</tr>
<tr>
<td>Austria</td>
<td>Long</td>
<td>0.68</td>
<td>0.44</td>
<td>0.25</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.65</td>
<td>0.17</td>
<td>−0.03</td>
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</tr>
<tr>
<td>Belgium</td>
<td>Long</td>
<td>0.88</td>
<td>0.82</td>
<td>0.69</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.26</td>
<td>0.22</td>
<td>−0.16</td>
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<tr>
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<td>−0.19</td>
<td>−0.30</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>−0.08</td>
<td>−0.20</td>
<td>−0.65</td>
<td>−0.93</td>
</tr>
<tr>
<td>France</td>
<td>Long</td>
<td>0.96</td>
<td>0.78</td>
<td>0.70</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.49</td>
<td>0.34</td>
<td>−0.02</td>
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<tr>
<td>Germany</td>
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<td>0.74</td>
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<tr>
<td></td>
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<td>0.73</td>
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<td>−0.19</td>
<td>−0.26</td>
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<tr>
<td>Italy</td>
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<td>0.97</td>
<td>0.92</td>
<td>0.86</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.77</td>
<td>0.32</td>
<td>0.35</td>
<td>0.39</td>
</tr>
<tr>
<td>Japan</td>
<td>Long</td>
<td>0.88</td>
<td>0.80</td>
<td>0.72</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.46</td>
<td>0.11</td>
<td>0.11</td>
<td>−0.39</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Long</td>
<td>0.82</td>
<td>0.45</td>
<td>0.45</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.36</td>
<td>0.18</td>
<td>0.17</td>
<td>0.10</td>
</tr>
<tr>
<td>Spain</td>
<td>Long</td>
<td>0.89</td>
<td>0.75</td>
<td>0.49</td>
<td>−0.19</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.71</td>
<td>0.21</td>
<td>0.09</td>
<td>−0.44</td>
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<tr>
<td>Sweden</td>
<td>Long</td>
<td>0.79</td>
<td>0.41</td>
<td>0.32</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.65</td>
<td>0.34</td>
<td>0.31</td>
<td>0.29</td>
</tr>
<tr>
<td>UK</td>
<td>Long</td>
<td>0.82</td>
<td>0.66</td>
<td>0.61</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.43</td>
<td>0.14</td>
<td>0.12</td>
<td>−0.04</td>
</tr>
<tr>
<td>US</td>
<td>Long</td>
<td>0.89</td>
<td>0.57</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Short</td>
<td>0.04</td>
<td>−0.07</td>
<td>−0.35</td>
<td>−0.87</td>
</tr>
</tbody>
</table>


Source: Authors’ calculations.

Estimates of persistence of greater than one were obtained in a few cases prior to the break. This generally was a result of the break in persistence occurring early in the sample when inflation was on a sharp upward trend, such as in Japan in the early 1970s.
Finally, we examine whether the estimate of persistence changes, once we allow for a single break in the mean. That is, we first find the most likely date for a break in the mean, and then the most likely date for a break in the slope of the AR(12) regressions. The results are reported in Figure 3. The estimates show declines in persistence in 12 of 19 countries, of which 8 are statistically significant at the 10% level.
4.2. The disaggregated data

Having identified changes in the mean of the aggregate inflation process, we now examine the component series. We study roughly 12 consumption categories for most of the countries. In total, we have been able to obtain 198 times series that can be used to estimate the AR(12) model. To get a flavour of the results, we begin with a histogram that displays the frequencies of the estimated AR(12) parameters, conditional on the number of assumed breaks in the mean of the individual inflation series. Figure 4 shows both the decline in estimated persistence once mean changes are allowed for, as evidenced by the leftward shift in the distribution, as well as the wide range of estimates across countries and components.\(^{12}\)

The descriptive statistics in Table 4 bear out the importance of the mean breaks. The fraction of estimates that are positive shrinks from 88%, with no mean breaks, to 61% allowing for one break, and then 49% when there are two breaks. It is also noteworthy that the size of the changes in estimated persistence is generally quite large. The addition of a single mean breaks drives down the persistence estimate of one-third of the component series by more than 0.5, with 74% of the series showing

\(^{12}\) We have done two types of robustness analysis using the component data. First, we have replicated the Robalo Marques (2004) analysis, examining mean breaks rather than autoregressive parameters. Second, we have performed the entire analysis assuming that the mean breaks in the component series occur at the dates of the mean break in the aggregate series. That is, we impose the break in the aggregate series on each of the components and examined the change in the persistence of the series. The results from both these two exercises generate the same conclusions as the ones we present.

\[\text{Figure 4. Frequency distribution of persistence in the components of inflation}\]
declines of more than 0.2. Results for the (mostly European) countries which have the shorter sample generally show less persistence.\textsuperscript{13}

Moreover, Table 4 shows that a large fraction of the estimates of persistence are small, even if there is no mean break. Even in the case of the countries for which we have the longer time series, which tend to have higher positive persistence, one half of the series have estimates of persistence below 0.69, while once we allow for one mean break, this declines to 0.38, and to 0.08 once three mean breaks are allowed for.\textsuperscript{14}

It is interesting to take the estimates and compute averages by product categories across countries. This provides some indication of whether the persistence in the aggregate inflation is a general feature of the price data or is attributable to any of a small number of the component series.

Table 5 reports the results of this exercise using data from those countries with the longer sample of data. As with the aggregate CPI data, there is a clear decline in estimated persistence as we control for breaks in the mean. Once we allow for breaks,

\textsuperscript{13} Using the Andrews and Ploberger (1994) Sup-F test, we find that slightly over 40\% of the series exhibit mean breaks that are statistically significant at the 10\% level.

\textsuperscript{14} We have also computed a set of results in which we restrict the break dates for the components to be the same across series within a country. The statistical analysis is approximate in that we choose the break date to maximize the value of the Quandt-style F-statistics averaged across the series. The results from this analysis are very similar to the one obtained from imposing the structural break date from the aggregate CPI series on each of the component. In both cases, our findings have the same character as the ones we report here. In the former case the similarity is not that surprising as we are approximately using a version of the aggregate CPI where the components are equally weighted.
very few components show any sizeable amount of positive persistence with the exception of housing and restaurants. Housing inflation is highly persistent for nearly all countries in the sample, and may well be related to the methodology of measuring prices employed by the statistical bureau. Certainly this is the case for the two countries with which we are most familiar, namely Australia and the United States, although in Australia’s case, recent changes in methodology mean this is no longer true.

Indeed it is the case that housing inflation is the most common source of high persistence, once we allow for mean breaks, in each of the nine countries for which we have the longer sample of data. It is interesting that the shorter sample European data do not have a housing component, which may be a possible cause of the low persistence in the data.

Inflation in the prices of clothing, food, recreation, transport and furniture tend to have high persistence when there are no mean breaks, but this declines markedly once we allow for breaks in the mean. Note that transport prices generally include petrol. The estimates of persistence for health, communication and alcohol are generally low.

Focusing on the countries with high aggregate persistence, even after allowing for mean breaks we find that persistence in only a few components is responsible for the aggregate persistence. For example, in Italy, after allowing for one mean break, aggregate persistence is 0.92, which is a result of persistence of 0.93 in furniture price inflation, 0.72 in unprocessed food inflation and 0.90 in restaurant food inflation. Persistence in the other price categories is below 0.5. Similarly, in the case of Japan, high persistence in housing, furniture and education is responsible for the high aggregate persistence while persistence in the other components is relatively low.

Overall, these results show that while flexible price-setting behaviour can be pervasive in many sectors of the economy, high persistence in only a few sectors can result

<table>
<thead>
<tr>
<th></th>
<th>No breaks</th>
<th>One break</th>
<th>Two breaks</th>
<th>Three breaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>0.69</td>
<td>0.40</td>
<td>0.21</td>
<td>0.07</td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.44</td>
<td>0.05</td>
<td>-0.10</td>
<td>-0.29</td>
</tr>
<tr>
<td>Clothing</td>
<td>0.68</td>
<td>0.21</td>
<td>0.10</td>
<td>-0.09</td>
</tr>
<tr>
<td>Housing</td>
<td>0.79</td>
<td>0.57</td>
<td>0.45</td>
<td>0.35</td>
</tr>
<tr>
<td>Furniture</td>
<td>0.79</td>
<td>0.45</td>
<td>0.37</td>
<td>0.25</td>
</tr>
<tr>
<td>Health</td>
<td>0.44</td>
<td>0.14</td>
<td>-0.01</td>
<td>-0.12</td>
</tr>
<tr>
<td>Transport</td>
<td>0.59</td>
<td>0.22</td>
<td>0.07</td>
<td>-0.06</td>
</tr>
<tr>
<td>Communication</td>
<td>0.45</td>
<td>0.02</td>
<td>-0.20</td>
<td>-0.33</td>
</tr>
<tr>
<td>Recreation</td>
<td>0.63</td>
<td>0.24</td>
<td>0.05</td>
<td>-0.07</td>
</tr>
<tr>
<td>Education</td>
<td>0.80</td>
<td>0.58</td>
<td>0.41</td>
<td>0.24</td>
</tr>
<tr>
<td>Restaurants</td>
<td>0.84</td>
<td>0.56</td>
<td>0.49</td>
<td>0.48</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0.58</td>
<td>0.33</td>
<td>0.25</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*Source: Authors’ calculations.*
in high aggregate inflation persistence. Thus, the evidence of low persistence in disaggregated price data presented by Bils and Klenow (2002) and others is interesting in terms of assessing the various theories of price-setting, but is less relevant for the conduct of monetary policy, which is concerned about the aggregate properties of inflation.15

This evidence argues against the proposition raised by Mankiw and Reis (2002) and Benigno (2004) that policy-makers should focus on those sectors of the economy where prices tend to be more rigid. It supports the rebuttal provided by Otmar Issing (2005): ‘by assigning higher importance to more rigid units, monetary policy would accommodate structural inefficiencies, ultimately creating perverse incentives. These difficulties would introduce some arbitrariness in the conduct of monetary policy and negatively affect the transparency and accountability of the central bank.’

4.3. The timing of the breaks

We next look at the timing of the estimated breaks in the inflation process to address several interesting questions:

• Do the breaks in the mean occur at the same time across commodity groups within a country? Or, alternatively, are they at the same time within commodity groups across countries?
• Do the estimated changes in persistence (conditional on one mean break) occur at the same time either across commodity groups within a country, or within a commodity group across countries?

Finally, we can look to see if the mean and persistence breaks occur at the same time.

Figure 5 summarizes the information on the timing of the breaks for the countries for which we have a longer run of data. In each case, the graph shows the date of the first and second mean breaks in aggregate inflation and its various subcomponents, as well as the timing of the break in persistence. For example, the panel for Canada shows that seven of the first mean breaks in inflation occurred in 1991, while three of the breaks in persistence occurred at about the same time.

Overall, there is little evidence that the timing of the breaks in the mean or the breaks in persistence have any similarity across countries. The breaks are dispersed throughout the sample period. The same statement is true if we look within product categories across countries. The breaks in mean inflation are neither a worldwide nor a sector-specific phenomenon.

We note that these results are unlikely to be a consequence of measurement differences across components. That is, we seriously doubt that less persistent series have more measurement error—which would create bias resulting in lower measured persistence. The reason is that price collectors tend to design their sampling strategies based on the difficulty in obtaining accurate prices. If, for example, a particular price varies quite a bit across outlets, then there is a tendency to put more resources in the collection of prices of that good or service. In other words, less persistent series are likely to be measured more accurately.
Figure 5. Frequency histogram of location of breaks in inflation series
Within countries, however, there is some evidence of a clustering of breaks in mean and persistence, particularly when we look at the longer sample. For New Zealand, there is commonality in break points around 1987, when the country embarked on a major programme of reform, including changes to its monetary policy framework.

In Australia, there is a clustering of mean breaks, and persistence breaks in the early 1990s, when the country went into recession and there was a marked drop in the level of aggregate inflation. This is also true of Sweden and the UK in the early 1990s, and Germany in the early 1980s. Similarly, there is a clustering of break points in Canada in 1991, when again there was a recession. In Canada, there was also an announced shift in the framework for monetary policy around this time, but it is not possible to disentangle the effect of this on price-setting behaviour from the effect of the recession. In the United States, there are breaks in the mean of inflation of a number of components around the time of the Volcker disinflation. Here again there is a change in monetary policy framework coincident with a contraction in economic activity, although there is also a clustering around the recession in the early 1990s.

In Japan, the breaks tend to occur in 1974, when the country suffered from the oil price shock. The oil price appears to have been translated into a shift in the mean of a number of components of inflation, as well as in their persistence.

Results for the subset of European countries (not presented here) do not display much commonality in the timing of breaks either across or within countries. There is little indication in these results that the changes in the operation of monetary policy associated with the operation of the ERM or the commencement of the European Monetary Union in 1999 had a material influence on the inflation process. Furthermore, for the sample of EU countries there is also not much evidence that the recessions of 1992 or 2001 had an impact on the inflation process.

Generally, there is little evidence that the change in mean coincides with the change in persistence. With the exception of Brazil and New Zealand, changes in the
mean of an inflation series are more than six months removed from the estimated break in persistence in over two-thirds of the series we investigated.

In light of these findings, it is important to ask what is causing changes in mean inflation. One possible source is shifts in inflation expectations. Other possible sources include technological factors affecting marginal cost and market structure that could influence the dynamics of markups. Obtaining cross-country data on such quantities is well beyond the scope of this study. Here we ask whether structural changes in inflation expectations are coincident with shifts in the mean of actual inflation.

To answer these questions, we have collected inflation expectations data for Australia, the US and the UK. For these three countries, we can obtain long enough time series to present a meaningful analysis. Table 6 reports the dates of the mean and persistence breaks for the aggregate inflation and inflation expectations series – the timing and frequency of the various series match. The correspondence is quite remarkable. Looking closely at the dates themselves, we note that they tend to be when the country was in a recession times or when the monetary policy regimes was changed (or both). It is also noteworthy that the shift in the mean of inflation expectations precedes (although only slightly) the shift in the mean of inflation. Table 7 shows the size of the breaks in the means of the inflation expectations series and compares them to the inflation series. Again, the similarity is striking. This evidence strongly suggests that changes in the process by which inflation expectations are formed has played a key role in the reduced persistence of observed inflation.

Table 6. Dates of mean breaks in inflation and inflation expectations

<table>
<thead>
<tr>
<th></th>
<th>1st mean break</th>
<th>2nd mean break</th>
<th>3rd mean break</th>
<th>Break in persistence</th>
<th>Break in persistence given 1st mean break</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>USA (Jan 1978–Mar 2004)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation expectations*</td>
<td>Jan-81</td>
<td>Dec-90</td>
<td>Nov-82</td>
<td>Jan-81</td>
<td>Jan-81</td>
</tr>
<tr>
<td>Aggregate CPI (y/y)</td>
<td>Sep-81</td>
<td>Dec-90</td>
<td>May-80</td>
<td>Apr-80</td>
<td>May-91</td>
</tr>
<tr>
<td>Aggregate CPI (m/m)</td>
<td>Mar-81</td>
<td>Oct-90</td>
<td>Aug-86</td>
<td>Feb-81</td>
<td>Oct-90</td>
</tr>
<tr>
<td><strong>Australia (Dec 1986–Sep 2003)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation expectations**</td>
<td>Sep-90</td>
<td>Mar-96</td>
<td>Sep-92</td>
<td>Sep-90</td>
<td>Mar-96</td>
</tr>
<tr>
<td>Aggregate CPI (y/y)</td>
<td>Dec-90</td>
<td>Dec-99</td>
<td>Mar-97</td>
<td>Mar-90</td>
<td>Dec-90</td>
</tr>
<tr>
<td>Aggregate CPI (q/q)</td>
<td>Dec-90</td>
<td>Jun-99</td>
<td>Sep-96</td>
<td>Jun-90</td>
<td>Jun-92</td>
</tr>
<tr>
<td><strong>United Kingdom (Feb 1983–Feb 2004)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation expectations**</td>
<td>Apr-90</td>
<td>Oct-88</td>
<td>Mar-97</td>
<td>Apr-90</td>
<td>Dec-89</td>
</tr>
<tr>
<td>Aggregate CPI (m/m)</td>
<td>Sep-90</td>
<td>May-88</td>
<td>Jun-83</td>
<td>Apr-90</td>
<td>Apr-90</td>
</tr>
</tbody>
</table>

* University of Michigan 1-year median inflation expectations.
** Bond Market inflation expectations (quarterly data for Australia, monthly for UK).

Source: Authors’ calculations.
4.4. The relationship between duration, persistence and variability

The theories discussed in Section 2 have implications for the relationship between the duration, persistence and the variability of innovations to inflation. They have the following important implications: 16

1. The longer the time between price changes, the more persistence there will be in the price level, and the more negative the persistence in price changes.
2. The longer the time between changes, the higher the variability of the innovations to inflation (in a reduced-form autoregression).
3. The more persistent are innovations to the mark-up over marginal cost (or the output gap) the more persistent is inflation.
4. The more backward-looking (or indexed) are pricing decisions, the more positive persistence there is in price changes.
5. The more aggressive monetary policy is in keeping inflation close to its target the higher the variability of innovations to inflation.

Our regressions yield information on persistence and the standard deviation of the innovations to inflation. In addition to this we include data on the duration of price

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16 For a detailed discussion of the theoretical basis for these statements see the summary in Section 2 of Angeloni et al. (2004).

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Table 7. Shifts in the mean of inflation expectations

<table>
<thead>
<tr>
<th>Number of mean breaks</th>
<th>Zero</th>
<th>One</th>
<th>Two</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before break</td>
<td>After break</td>
<td>Before 1st break</td>
</tr>
<tr>
<td>USA (Jan 1978–Mar 2004)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation expectations*</td>
<td>3.9</td>
<td>8.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Aggregate CPI (y/y)</td>
<td>4.2</td>
<td>10.2</td>
<td>3.3</td>
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<tr>
<td>Aggregate CPI (m/m)</td>
<td>3.9</td>
<td>9.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Australia (Dec 1986–Sep 2003)</td>
<td></td>
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<td></td>
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<tr>
<td>Inflation expectations**</td>
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<td>8.2</td>
<td>3.2</td>
</tr>
<tr>
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<td>3.7</td>
<td>7.5</td>
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<tr>
<td>Aggregate CPI (q/q)</td>
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<td>7.5</td>
<td>2.3</td>
</tr>
<tr>
<td>United Kingdom (Feb 1983–Feb 2004)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation expectations**</td>
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<td>6.9</td>
<td>3.8</td>
</tr>
<tr>
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<td>5.4</td>
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<td>Aggregate CPI (m/m)</td>
<td>3.8</td>
<td>5.9</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Notes: See Tables 1 and 6.

Source: Authors’ calculations.
changes for the categories of goods that broadly correspond to the ones used in our analysis for eight European countries and the United States (from Bils and Klenow, 2002).\(^{17}\)

We examine three regressions. In the first we regress the standard error of the inflation regressions on duration (controlling for country-specific fixed effects which may be a proxy for the monetary regime that is present). In the second we look for a correlation between persistence and duration (again, both with and without). Finally, we regress our measure of persistence on the estimated standard deviation of the inflation innovations in the autoregressions.\(^{18}\)

| Table 8. The relationship among persistence, duration, and variability |
|--------------------------------------------------|--------|--------|--------|--------|
| A. Variability and duration & No breaks & One break & Two breaks & Three breaks |
| Regression without fixed effects & Coefficient estimate & 0.01 & 0.02 & 0.02 & 0.02 |
| & t-statistic & 1.01 & 1.38 & 1.44 & 1.18 |
| Regression with fixed effects & Coefficient estimate & 0.01 & 0.02 & 0.02 & 0.02 |
| & t-statistic & 0.97 & 1.14 & 1.18 & 1.00 |
| B. Persistence and duration & No breaks & One break & Two breaks & Three breaks |
| Regression without fixed effects & Coefficient estimate & 0.00 & 0.00 & 0.00 & 0.00 |
| & t-statistic & -0.28 & -0.25 & -0.23 & -0.20 |
| Regression with fixed effects & Coefficient estimate & -0.01 & -0.01 & -0.01 & -0.01 |
| & t-statistic & -1.00 & -0.96 & -0.96 & -0.95 |
| C. Persistence and variability & No breaks & One break & Two breaks & Three breaks |
| Regression without fixed effects & Coefficient estimate & -0.15 & -0.35 & -0.35 & -0.32 |
| & t-statistic & -2.18 & -3.12 & -2.73 & -2.07 |
| Regression with fixed effects & Coefficient estimate & -0.69 & -0.83 & -0.98 & -1.03 |
| & t-statistic & -8.30 & -7.00 & -7.39 & -6.49 |

Notes: Regressions of the estimated sum of the coefficients in AR12 (or AR4) autoregressions on the standard error of the regression across countries and components. Fixed effects regressions allow the constant to differ for each country. Regressions in panels A and B, with duration, are based on data from 9 countries with 90 time series. Regressions in panel C utilize the entire data set of 19 countries and 202 time-series. Reported t-statistics are robust to heteroscedasticity.

Source: Authors’ calculations.

\(^{17}\) The data on duration were obtained from a number of sources. The US data are from Bils and Klenow (2002, Table 3). Data for Austria, Belgium, Finland, France, Italy, Netherlands, Portugal and Spain are from the papers summarized in Dhyne et al. (2005). Unfortunately, the coverage of the duration data – both in terms of the commodity cross-section and the times-series sample – does not exactly match our component data. Unfortunately, this is the best that we can do.

\(^{18}\) It is possible that our results are driven by measurement error caused by the fact that our inflation and duration data do not match well. The duration data is computed over different sample periods and often uses subsets of the consumer price data. This mismatch in the timing and coverage of the duration data mean that the coefficient estimates in the regression of volatility and persistence on duration will be biased toward zero.
The results, reported in Table 8, show that duration is uncorrelated with both persistence and variability of inflation innovations. This is evidence against implications 1 and 2. However, persistence and variability are highly negatively correlated. These results are strengthened by the inclusion of country-specific fixed effects. The relative importance of country fixed effects in all of our regressions (half of them have p-values less than 0.05) suggests a clear role for monetary policy supporting implication 5.

We interpret these results as consistent with Fuhrer’s (2005) conclusion that persistence in the mark-up is not the source of persistence in inflation. Instead, backward-looking expectations, or indexation, are responsible. Our argument has two parts. First, there is no reason to believe that what we are finding is a consequence of omitting other possible drivers from the persistence regressions in panel C of Table 8. Such variable should not have any particular relationship with variance of the innovations in the inflation regressions. Second, as Gali (2004) outlines, more price rigidity generates more backward-looking behaviour and hence more persistence. Intuitively, firms facing bigger shocks – either to demand or costs – will be less backward looking. The more volatile the environment, the more flexible the firm’s pricing policy will have to be and the less inertia it can exhibit.

5. CONCLUSION

The main result of this paper is that the most significant change in the inflation process has, not surprisingly, been in its mean. We show that the conventional wisdom, that inflation has a high level of persistence, is not robust. Once we allow changes in the mean, measured inflation persistence falls considerably. This is true for both aggregate consumer prices and for its components parts. We do find some support for the view that inflation persistence has fallen over the past few decades, but the size of the decline is generally small.

Looking at the constituent parts of the consumer price series – food, clothing, furniture, housing and the like – we find that the persistence in one component of inflation is often enough to generate the amount of persistence we see in the aggregate series. This is a consequence of the fact that aggregate inflation inherits the persistence of its most persistent disaggregated component. This means that central bankers can achieve their objective of stabilizing inflation in the sector with nominal rigidities by targeting aggregate inflation. Policy-makers need not go to the trouble of distinguishing the flexible from the sticky-price sectors. By basing decisions on the aggregate, they will automatically focus on the latter.

While one can argue that the changes in monetary policy frameworks have contributed to a reduction in the mean of inflation, it is much harder to make the case that they have had a meaningful impact on persistence. Looking at the timing
of shifts in average inflation across commodities within individual countries suggests that the relationship between changes in the monetary framework and changes in the mean of inflation is far from perfect (although the data we have for the euro area may post-date the significant changes in monetary frameworks in those countries). There are some important exceptions, including the disinflations in the US in the early 1980s and in New Zealand in the late 1980s. Both episodes arguably entailed a change in the monetary framework. Recessions also have some influence and are sometimes simultaneous with changes in monetary frameworks.

The important role played by changes in the mean of inflation in our results highlights the need to take account of changes in inflation expectations when considering sacrifice ratios – measures of the transitory output losses that generally accompany permanent reductions in inflation. We present some evidence that the change in the mean is directly related to changes in inflation expectations. If inflation expectations have less persistence because of increased credibility in the monetary framework, then there will not be a need for the central bank to engineer a decline in output below potential to return inflation to its desired level.

Taken as a whole, our results suggest that inflation can be thought of as a relatively stable process with very little persistence, albeit one that is punctuated by large occasional shifts in the level. We produce evidence consistent with the view that these large shocks, coupled with monetary policy reactions that allow or engender shifts in the mean of inflation, arise from shifts in inflation expectations. The rest of the time, persistence is modest as the monetary policy response, or the credibility of the framework, ensures that the shocks do not translate into mean shifts.

Our results remain only suggestive, because we have neither produced an exhaustive catalogue of the sources of inflation dynamics, nor measured their relative importance in explaining the observed changes in the inflation process. It would be important to examine possible changes in other inflation driving processes, including marginal costs and competitive structure, and our study of the dynamics of inflation expectations is also sufficiently crude to leave clear room for additional work.

Discussion

Manuel Arellano
CEMFI

The objective of this paper is to measure the degree of inflation persistence for different countries and for different components of the CPI. Data from 19 countries and up to 12 categories of goods are used. The main finding is that inflation
persistence is much lower after controlling for mean shifts. This paper belongs to a recent but intense literature that has looked at reduced form measures of inflation persistence from univariate time series models. Its findings essentially agree with those of other papers using different subsets of countries or sectors, and other statistical measures of persistence. What makes this paper particularly useful is that it is the most comprehensive study of its kind to date.

**Mean breaks and persistence**

The results are based on the observation that, since mean inflation differs for different time intervals, measured correlation between inflation and its lags will depend on how much change is allowed in the means. If there is a mean break but we ignore it, it will be mistaken for persistence. Unfortunately, if we allow for inexistent mean breaks, estimated persistence may be downward biased.

Also, if there are two types of shocks to inflation (high and low persistence), using mean breaks will tend to mitigate the contribution of the persistent shocks to an overall measure of persistence. In fact, Perron's (1989) original motivation was to model rare shocks as one-time events using dummy variables. This raises doubts on the appropriate measure of persistence in the absence of prior information about regime shifts. In choosing a measure of persistence as a guide for monetary policy we are forced to take a stand on the nature of shifts in mean inflation. Is high inflation a thing of the past? That is, is our prior of the mean inflation process such that we would assign no weight to the possibility of further shifts in mean inflation in calculating inflation forecasts?

So a general worry is that an agnostic univariate time-series analysis may not be able to separately identify the mean process and the amount of dependence around it, so that we are faced with a menu of estimates of persistence ranging from low to high depending on the choice of technique. The nice aspect of the present paper is the use of components of inflation within countries, which help in making inferences about the size and timing of breaks.

**Timing of the breaks**

An interesting possibility is the estimation of persistence for each of the commodity groups in a country (including the aggregate as an additional group) imposing the same time for the breaks in the means (i.e. a partial pooling). This is in line with the univariate approach adopted in the paper and it seems promising in view of the evidence of clustering of breaks. This possibility is statistically meaningful because in this way we can get more reliable estimates of mean shifts. The width of the confidence interval for the break date does not decrease with sample size, but it is inversely related to the number of series which have a common break date (as shown by Bai et al., 1998).
It is also economically meaningful because it can be argued that we are interested in common breaks, since that would be the case for changes in monetary policy regimes. If doing this we still get a low level of persistence in the aggregate CPI, then we can have greater confidence in the conclusions. Another possibility would of course be to use explicit determinants of the long-run mean inflation, such as indicators of monetary policy regimes or of methodological changes in price measurement.

Changes in inflation volatility

The paper examines the possibility of association between breaks in means and breaks in persistence. It would be of interest to test for a break in the mean allowing simultaneously for a break in the volatility of inflation shocks. Such a procedure would be coherent with evidence that high inflation is associated with high inflation volatility, and it could lead to a better determination of breaks.

Implications for targeting

The conclusion that there is no need to target high rigidity sectors because the aggregate inherits the properties of the most persistent components may be premature. The result of Altissimo et al. (2004) shows that the persistence of the aggregate critically depends on the form of the heterogeneity of persistence measures across sectors (e.g. how much mass there is near unity), which itself varies from one country to another. The illustration in Box 2 suggests that caution is needed. There we have two component series, one has persistence of 0.1 and when the other has persistence of 0.95, the persistence of the aggregate is only 0.58. Targeting a degree of persistence of 0.58 may be very different to targeting one of 0.95.

Implications for theories of price determination

It is not clear how strong is the claim that finding reduced-form low inflation persistence is more supportive of price determination theories than those of the previous literature.

To make that link, at a minimum one would have to measure the partial effect of lagged inflation net of changes in marginal costs, but I agree that this could be the subject of another paper.

The paper reports a strong negative correlation between persistence and variability in shocks. Suppose for the sake of the argument that persistence and variability were the same for all series. In that case, the correlation between the estimates of persistence and variability would exclusively capture the correlation in the sampling distribution of the estimators of the two quantities, because the two estimates are calculated from the
same data. Since sampling covariances could be large, it would be useful to assess to what extent the estimate of the substantive correlation of interest is affected by sampling errors.

Results

There is a substantial degree of persistence in important countries after allowing for three breaks, such as Italy, France, Germany, Belgium or Japan, so that we may still have an inflation persistence puzzle relative to theoretical predictions.

It is nice to have a set of results as comprehensive as possible, using whatever sample periods are publicly available. However, the results for shorter periods are less interesting, in the sense that breaks are less interpretable and noisier.

Finally, according to Table 1, in 11 countries we observe fluctuations in mean inflation (mean inflation rises, then falls), which is hard to reconcile with the result of a one-off credibility battle.

Pierre-André Gourinchas

UC Berkeley

Cecchetti and Debelle have written a stimulating paper. It makes a deceptively simple point: inflation persistence is lower than previously believed. The central reason is the significant evidence of at least one break in the mean of the inflation process for many industrialized countries over the last 20–30 years. Standard estimates that neglect such breaks in means yield upward-biased measures of the persistence of inflation rates. The authors find that the median inflation persistence falls substantially once we allow for a break in means.

This is an important observation, for policy-makers and academics alike. For policy-makers, it indicates that the sacrifice ratio (the output cost of reducing inflation) may be low, since inflation tends to revert naturally back to its long-run mean. When mean inflation is low, this implies that rooting out bursts in inflation may be less costly or lengthy than previously estimated. For academics, this raises the question of the origins of this decline in mean inflation. For both, this should also lead to a reassessment of the goodness of fit of the monetary models commonly used by central banks to form projections of future inflation rates in response to various shocks and under a variety of scenarios for current and future monetary policy.

As the authors are well aware, others have previously documented breaks in the mean of the inflation process for many countries (see the references to the literature in the paper). Their contribution goes beyond previous work in looking at various subcomponents of the CPI and in documenting breaks in means both for the various subcomponents series and inflation expectations.

I organize my comments around two issues. First, I will discuss the methodology adopted in the paper. Second, I will make some observations on how their results should be interpreted in the context of modern monetary policy theory.
Methodology

The approach followed in the paper consists in estimating the autocorrelation of the inflation process in a univariate setting. The approach is most easily understood if we suppose that the inflation rate \( \pi_t \) follows an AR(1) with an autocorrelation coefficient \( 0 < \rho < 1 \), a mean \( \bar{\pi} \) and an innovation \( u_t \):

\[
\pi_{t+1} - \bar{\pi} = \rho(\pi_t - \bar{\pi}) + u_{t+1}.
\]

Usual estimation assumes that both the mean \( \bar{\pi} \) and the persistence coefficient \( \rho \) are constant. Clearly, allowing the mean \( \bar{\pi} \) to change over time would influence estimates of the persistence process. At one extreme, suppose that we allow \( \bar{\pi} \) to vary period by period. Then, the equation is exactly satisfied with \( \pi_t = \bar{\pi} \), for any value of the persistence process \( \rho \) (and \( u_{t+1} = 0 \) for all \( t \)). So some discipline must be imposed in allowing \( \bar{\pi} \) to vary over time. The approach in this paper is to allow \( \bar{\pi} \) to change a small number of times and to let the data tell us when these breaks in means occur. Conditional on allowing \( \bar{\pi} \) to change a few times, one can still identify and estimate \( \rho \).

A key question is how to interpret these shifts in the mean of the inflation process. One natural interpretation is that it coincides with a shift in regime, associated, for example, with a change in the paradigm followed by the monetary authorities. The changes in \( \bar{\pi} \) would then reflect changes in the expectations of long-run inflation held by the private sector in response to this change in paradigm. This is the interpretation favored in the paper; and the empirical evidence for a few countries is indeed somewhat supportive. For instance, the paper mentions that the largest number of breaks occurs in 1987 in New Zealand when the country adopted a set of macroeconomic reforms. For the United States, the largest number of breaks occurred in 1980–81, around the time of the Volcker disinflation.

For many other countries, however, the breaks in the CPI and its components concentrate around recessions (Australia, Sweden, UK, Germany and Canada). This is more problematic to interpret. A decline in inflation is quite natural during recessions but, absent some structural change in the conduct of monetary policy, a recession should not be associated with a permanent shift in the expected long-run level of inflation. Also, it is clear that not all recessions result in mean shifts in the inflation process. Why some recessions should be associated with such breaks remains somewhat of a mystery.

Furthermore, dispersion in estimated break dates between the CPI and its various components casts doubt on a ‘shift in monetary regime’ interpretation of the results, which would imply a decline in mean inflation occurs across the board for both the CPI and its various components. At the very least, if a monetary reform is implemented at time \( t \), the components of the CPI should exhibit a mean-shift after time \( t \). But the evidence presented in Figure 5 of the paper indicates that some series had breaks many years before what could arguably be construed as a monetary policy shift. To gather more evidence on the ‘regime-switching’ hypothesis, one might
estimate the dates of a potential regime switch in a first stage using data not only on inflation rates, but also on interest rates, money supply, output growth and the output gap, as well as monetary policy narratives to establish a set of estimated breaks for each country in the sample.

When interpreting the results of such estimation exercises, it would be important to consider an alternative explanation for the decline in mean inflation, which lies in the increased integration of goods markets. One often-heard argument is that globalization of goods markets has driven markups down, by, for example, making demand curves more elastic. If so, the timing of the decline in mean inflation could be connected to the increased openness of goods markets. This would presumably be more relevant for EU countries, than say, the US, allowing for some sample variability. More generally, it would be interesting to relate more systematically price-setting policies and the global competitive environment faced by different countries.

**Implications for theoretical models**

My second comment concerns the interpretation of the results in the context of modern monetary models à la Woodford (2003). The paper presents a motivation for its findings based on the observation that inflation has little or no persistence in standard New Keynesian models (Ball, 1994 and Fuhrer and Moore, 1995).

A traditional ‘fix’ of the model is to assume that prices that are not re-optimized at time \( t \) are indexed to past inflation, instead of remaining constant as in the usual Calvo pricing model. This creates a dependency of actual inflation upon past inflation in the aggregate supply relationship, where the coefficient on past inflation reflects the economy-wide degree of indexation. The log-linearized aggregate supply relation takes the following form (see equation (3.6) in Woodford, 2003, p. 215):

\[
\pi_t = \gamma \pi_{t-1} + \kappa \sum_{j=0}^{\infty} \beta^j E_t [\hat{Y}_{t+j} - \hat{Y}^n_{t+j}]
\]

where \( \hat{Y}^n_{t+j} \) represents the natural level of output, \( \hat{Y}_{t+j} + \hat{Y}^n_{t+j} \) the output gap (in percentage terms) and \( \gamma \) measures the degree of indexation of prices on past inflation.

It is important to understand that \( \gamma \) is not the same thing as \( \rho \), the autocorrelation of inflation rates. \( \gamma \) measures the autocorrelation of inflation *once we control for current and future expected changes in the output gap*. Since the output gap itself is serially correlated, it is entirely possible to observe a serially correlated inflation process, even if there is no inflation inertia (see Whelan, 2004 for a similar point). Consider the case where the output gap follows an AR(1) with persistence \( 0 < \rho' < 1 \). Manipulating the aggregate supply equation shows that inflation follows an AR(2) and that the sum of AR coefficients (the equivalent of what is measured in the paper) is equal to \( \gamma(1 - \rho') + \rho' \). In the limit case where \( \gamma = 0 \), this is equal to \( \rho' \) and inflation inherits
The persistence process of the output gap. In fact, the larger is $\rho$ the less the sum of AR coefficient depends upon $\gamma$.

The implication is obvious: evidence of high persistence in inflation rates does not conflict with the theory, as long as the output gap itself is persistent. Further, if we observe that the output gap is proportional to the average real marginal cost, we can directly check whether the inflation process is consistent with the behavior of the real marginal cost. Building on this insight, Sbordone (2002), Galí et al. (2001) and others have found that the predictions of the Calvo pricing model explain remarkably well the actual path of inflation, both at high and low frequency, over the postwar period (see Woodford, 2003, chapter 3 for a summary).

What should one make, then, of the evidence in this paper on low inflation persistence and breaks in means? One possibility is that there is also a break in means in the real marginal cost itself or in the output gap. Stock and Watson (2003) find evidence that the persistence of output growth has in fact increased for Canada, France and the UK, and decreased for Germany and Japan. Similarly, Blanchard and Simon (2001) find that the persistence of US output growth has remained mostly unchanged, while the volatility of output and inflation has decreased over time. It is possible, however, for the persistence of the output gap or real marginal costs to decrease even as the persistence of output growth increases or remains unchanged. In fact, the output gap can become less persistent in an environment where natural output become more persistent, if for instance, monetary policy improves and leads to shorter-lived response to output shocks. The paper does not discuss such issues in depth. It focuses instead on the possibility that inflation expectations shifted from a ‘high’ long-run inflation to a ‘low’ long-run inflation, while leaving the persistence of real marginal costs or the output gap unchanged. This raises a puzzle, however, since the empirical evidence does indicate that the dynamics of the real marginal cost can account for the lower persistence of inflation. The good fit of inflation and real marginal cost dynamics can be reconciled with the paper’s evidence on shift in means and lower persistence by a secular decline in the volatility and persistence of output gaps as well as of inflation. Blanchard and Simon (2001) argue for such secular decline in output growth and inflation volatility against the alternative of a shift in average volatility, temporarily halted by the macroeconomic developments on the 1970s.

While the univariate results are important, it is not clear exactly how to connect them to what we understand of the price formation process and the link between inflation, inflation expectations and the output gap. This is symptomatic of a larger problem with a univariate analysis of the inflation process. Even if the estimates indicate a break in means or persistence, this is likely to be insufficient to tease out the proximate and ultimate causes of these changes in the inflation process. What is missing from this discussion, of course, is how monetary policy affects the dynamics of the real marginal cost or the output gap, and how it itself may have changed over the sample period. While it may not be tractable to develop a full-fledged
price setting model with optimal monetary policy to analyse inflation dynamics in a large number of countries, one is left with the impression that this is precisely what is needed in order to gain a more systematic understanding of inflation dynamics. The paper’s important finding should stimulate further research in that direction.

Panel discussion

Olivier Blanchard found it very interesting that regime breaks in inflation expectations are estimated to occur before regime breaks in realized inflation processes. In all three cases, however, the breaks occurred at times of recession, rather than of clear policy-framework changes. Guy Debelle replied that simultaneous breaks in disaggregated inflation series, even when occurring during recessions, may well be taken to signal a change of monetary policy expectations.

Steve Nickell wondered whether the paper’s approach could be extended and refined so as to offer precise guidance in real-life policy problems, such as those arising when a one-off increase of energy prices causes inflation. In the absence of expectational and second round effects (such as on wage-setting), there would be no persistence in inflation, and no monetary policy response would be needed. But if a sequence of such shocks occurs, lack of monetary policy response would potentially damage credibility. Results such as those reported in the paper could perhaps give some indication of how large and how persistent shocks have to be before inaction leads expectations to diverge from the monetary authorities’ inflation target.

Hélène Rey pointed out that it is hard for univariate analysis to offer such structural indications, and mentioned that the degree of persistence in aggregate inflation can depend importantly on the extent of inter-sectoral heterogeneity. Carlo Favero noted that the paper’s evidence of regime breaks in international data interestingly challenges a consensus view, based on US inflation data, that model stability is not rejected when allowing for heteroscedasticity.

APPENDIX: DATA SOURCES

Price data

All data were seasonally adjusted using X-12, except for the US where the data were seasonally adjusted by the Bureau of Labour Statistics and Germany where the data were seasonally adjusted by the Bundesbank.

Australia: Quarterly CPI data published by the Australian Bureau of Statistics data, provided by the RBA. Sample from September 1969 to September 2003 for CPI,
food, alcohol, clothing, housing, furniture (household goods), and transport; from September 1980 for communication; from March 1982 for education, recreation; from September 1989 for health, miscellaneous.

**Austria**: HICP data published by Eurostat, provided by the ECB. Sample from January 1987 to January 2003. CPI data published by Statistics Austria. Sample from January 1960–May 2005.


**Brazil**: IPCA data published by Brazilian Institute of Geography and Statistics. Sample from August 1991 to October 2003.

**Canada**: CPI data published by Statistics Canada, provided by the Bank of Canada and the BIS. Sample from January 1984 to October 2003.

**Chile**: CPI data published by the National Bureau of Statistics, provided by Banco Central de Chile. Sample from April 1989 to December 2003 for the CPI, January 1997 to December 2003 for food, housing, furniture (home appliances), clothing, transportation, health, education and leisure and miscellaneous.

**European Union**: HICP data published by Eurostat, provided by the ECB. Sample from January 1990 to January 2003 for CPI, food, alcohol; from January 1995 to January 2003 for other components.

**Finland**: HICP data published by Eurostat, provided by the ECB. Sample from January 1987 to January 2003 for CPI, food, alcohol; from January 1995 to January 2003 for other components.

**France**: HICP data published by Eurostat, provided by the ECB. Sample from January 1990 to January 2003. CPI data published by INSEE. Sample from January 1970–May 2005.

**Germany**: CPI data provided by the Bundesbank. Sample from January 1962 to December 2004, with data for West Germany used prior to 1995 and pan-German data used post 1995.

**Italy**: HICP data published by Eurostat, provided by the ECB. Sample from January 1977 to December 2004.

Luxembourg: HICP data published by Eurostat, provided by the ECB. Sample from January 1995 to February 2003.

The Netherlands: HICP data published by Eurostat, provided by the ECB. Sample from January 1995 to February 2003, except the aggregate HICP from October 1987 to February 2003.

New Zealand: Quarterly CPI data published by Statistics New Zealand, provided by the RBNZ. Sample from March 1975 to September 2003 for CPI, food, clothing (apparel), transportation, alcohol, household operation, credit services; from December 1988 to September 2003 for housing, recreation and education, health.


Expectations data

Australia: Bond market expectations provided by Reserve Bank of Australia. Sample from December 1986 to September 2003 (quarterly).


United States: Survey of Professional Forecasters, expectations for the current year. Available from the Federal Reserve Bank of Philadelphia. Sample from September

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