Trend Inflation in Advanced Economies*

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Abstract

We derive estimates of trend inflation for fourteen advanced economies from a framework in which trend shocks exhibit stochastic volatility. The estimated specification captures time-variation in the degree to which longer-term inflation expectations are well anchored in each economy. Our results bring out the effect of changes in monetary regime (such as the adoption of inflation targeting in several countries) on the behavior of trend inflation.

Our estimates expand on the previous literature in several dimensions: For each country, we employ a multivariate approach that pools different inflation series. Our inflation gap estimates—defined as the difference between trend and observed inflation—are allowed to exhibit considerable persistence. Consequently, the fluctuations in estimates of trend inflation are much lower than those reported in studies that use stochastic volatility models in which inflation gaps are serially uncorrelated. This specification also makes our estimates less sensitive than trend estimates in the literature to the effect of distortions to inflation arising from non-market influences on prices, such as tax changes.

* The views in this paper do not necessarily represent the views of the Federal Reserve Board, or any other person in the Federal Reserve System or the Federal Open Market Committee. Any errors or omissions should be regarded as solely those of the authors.

Introduction

Measures of trend inflation play an important role for the study of inflation in many countries. In the context of policy analysis, the level and variability of trend inflation can be viewed as yardsticks of the degree to which inflation expectations in a particular country remain anchored over time. In addition, trend inflation can serve as a useful centering point in the construction of inflation forecasts at different horizons. Previous studies have also found that an important amount of the observed persistence of international inflation data are accounted for by variations in trend inflation, often related to changes in monetary regimes; see, for example, Levin and Piger (2002), Cecchetti, Hooper, Kasman, Schoenholtz, and Watson (2007) and Wright (2011).

In this paper we present estimates of the level and time-varying uncertainty of trend inflation for fourteen advanced economies. The estimates are derived from a multivariate model that pools information from different inflation series for each country. The model is applied on a country-by-country basis, in contrast to an approach of pooling information across countries (such as in Ciccarelli and Mojon, 2010). Our motivation for this choice is twofold: First, the country-by-country approach allows comparing different trend models across different samples of data. Second, while there are clearly some cross-country comovements in overall inflation, such common factors do not directly correspond to the components of a trend-cycle decomposition, as reported for example by Ciccarelli and Mojon (2010). In particular, as will be shown below, there are also considerable differences in each country's trend estimates, reflecting country-specific developments in monetary regimes and other forces.

Formally, we adopt the definition of trend inflation as the infinite horizon forecast of inflation. This trend definition corresponds to the Beveridge-Nelson (1981) concept, which has been applied to inflation data in a number of studies, including Stock and Watson (2007, 2010), Cecchetti et al (2007) and Cogley, Sargent and Surico (2013), as well as in some variation also by Cogley and Sargent (2005), Cogley, Primiceri, and Sargent (2010) and Kozicki and Tinsley (2012).[1]

Our multivariate model builds in the assumption that, for a given country, different inflation measures share the same common trend. Specifically, we consider changes in core and headline CPI as well as changes in the GDP deflator, assuming that the deviations that these inflation series exhibit from the common trend are stationary.

Our multivariate model nests the popular unobserved components model with stochastic volatility, simply known as "UCSV" model, of Stock and Watson (2007, 2010) that has been applied to G7 inflation data by Cecchetti, Hooper, Kasman, Schoenholtz, and Watson (2007).

[1] Cogley and Sargent (2005) and Cogley, Primiceri, and Sargent(2010) derive their measure of trend inflation from a non-linear function of time-varying VAR coefficients is identical to the Beveridge-Nelson trend in approximation. Kozicki and Tinsley's (2012) refer to their measure as the "shifting endpoint of inflation expectations." In a similar spirit, Levin and Piger (2002) relate time-variation in inflation persistence to structural breaks in the intercepts of autoregressive time-series models for inflation.

Our model extends the UCSV approach in two dimensions. First, as in Mertens (2011), the model extracts its trend estimates from multiple inflation series, instead of conditioning on a single inflation measure. Second, while deviations from trend are assumed to be serially uncorrelated in the UCSV model, inflation gaps can be, and typically are, persistent in our model, but are constrained to be stationary.

As in the UCSV model, we track two measures of stochastic volatility; one for trend shocks and the second one capturing changes in gap volatility. What makes the model tractable is the assumption that a single stochastic volatility measure drives changes in the volatility of all three gaps in our model.[2] A more general approach, embedding separate stochastic volatilities for each gap, would not only be more costly to compute but even much less sensible to implement in our data sample, when there is missing data.[3] In the same vein, we have also chosen to limit time-variation in model parameters to stochastic volatility, keeping inflation gap persistence constant.[4]

Since our estimation relies on state-space methods, with a limited number of time-varying parameters, we can well handle cases in which observations are missing for particular inflation series. Throughout, our estimation uses data since 1960, as far as available.

The remainder of this paper is structured as follows: Section 2 describes our data set for 14 industrialized countries. Section 3 lays out the empirical models used throughout the paper. Section 4 presents estimates for level and variability of trend inflation derived from univariate and multivariate models. Section 5 reviews periods in which price shifts occurred and their influence on the estimates. Section 6 concludes the paper.

2. International Inflation Data

Our dataset consists of quarterly inflation data for 14 developed countries from 1960:Q1 through 2012:Q3. To the extent that data availability permits, we use three different inflation measures for each country: headline CPI, core CPI and the GDP deflator. Details on the available data for each country are provided in Table 1. All CPI data are obtained from the Main Economic Indicators (database) produced by the OECD.[5] All GDP deflator data are obtained from the International Financial Statistics (database) maintained by the IMF with the exception of the

[2] Gap shocks can have arbitrary correlations as well as relative variances, for tractability these statistics are however assumed to be time-invariant in our model.
[3] Our approach of restricting stochastic volatility to a scale factor operating on multiple variables follows Carriero, Clark, and Marcellino (2012), who report considerable gains in fit and accuracy, compared to an unrestricted approach, in Bayesian VARs.
[4] For the United States, see the Cogley and Sargent (2005) and Cogley, Primiceri, and Sargent (2010) studies noted above.
[5] The only exception is the data for Ireland's headline CPI, which was compiled from the *IMF's International Financial Statistics*.

deflator series for Sweden that is from the Main Economic Indicators.[6] All GDP deflators from the IFS are seasonally adjusted except for Belgium, Ireland and Sweden. A simple filter was applied to these series to remove seasonal patterns over the entire period to keep consistent with the other series.[7] All inflation measures are computed as annualized quarterly log-differences.

[Table 1 about here]

For many countries, our sample encompasses periods over which recorded prices levels were likely distorted by nonmarket forces, like government price controls and major changes in indirect taxes.[8] Section 3 will discuss these episodes, and their effects on our estimates, in more detail. An overview of these dates is given in Table 2.

[Table 2 about here]

3. Model Description

Our paper uses two different models to estimate measures of trend levels and variability and to construct inflation forecasts. Both models are time-series models that use the same trend concept. The models mainly differ in the data on which their estimates are conditioned. The first model is the univariate UCSV model of Stock and Watson (2007, 2010), which is applied to data for each country's CPI inflation (headline). The second model is the multivariate common-trend model of Mertens (2011), which we estimate using data on three inflation series for each country (employing headline and core CPI as well as changes in the GDP deflator). As will be detailed below, both models use the trend concept of Beveridge and Nelson (1981), and both allow for time-varying volatility in trend shocks. The UCSV model embeds the assumption that deviations between actual inflation and trend have no persistence, whereas the multivariate model uses a (time-invariant) VAR to describe the dynamics of deviations between data and trend. While the UCSV model has two separate sources of stochastic volatility—one for trend shocks, the other for transitory shocks to inflation—only the trend shocks have stochastic volatility in the common-trend model.

[6] The two exceptions to this are the GDP deflators for Italy and Japan. The data provided by IFS showed rebasing problems, so deflator series from Stock and Watson (2003) starting in 1960:Q1 were spliced together with IFS data from 2000:Q1 to 2012:Q3.

[7] This simple filter consisted of a regression of a quarterly indicator on the ratio of the price level and its corresponding centered four-quarter moving average as the dependent. The coefficients were used to help remove seasonal patterns over the whole sample period.

[8] Some dates were excluded only from the GDP deflator series because of rebasing errors. The level series for Belgium, Canada, Germany, Italy, Spain and Switzerland all included large escalations in the price level that are not present in other literature such as Stock and Watson (2003). These dates are not included in the analysis on price shift dates. The dates removed from all estimations are 1966:Q1 (Italy), 1981:Q1 (Spain), 1991:Q1 (Germany), 1995:Q1 (Canada), and 1999:Q1 (Belgium and Spain).

Throughout this paper, we employ a Beveridge-Nelson decomposition of inflation into a trend level $\tau_t$and inflation gap $\widetilde{\pi_t}$. As described below, the two models used in this paper differ in their implied dynamics for the inflation gap,. In both models, the Beveridge-Nelson trend measures each model's long-run forecast of inflation:

$$\pi_t = \tau_t + \widetilde{\pi_t} \qquad \tau_t = \lim_{k \to \infty} E_t \pi_{t+k}$$

Since the trend is defined as a martingale it follows a Random Walk driven by serially uncorrelated disturbances $\overline{e_t}$:

$$\tau_t = \tau_{t-1} + \overline{e_t}$$

This specification also imparts a random walk component to inflation. Whether this nonstationary component has relevant effects on observed inflation dynamics depends on the relative size of variations in trend and inflation gap. Our desire is that the estimates to capture situations in which inflation expectations are well anchored and trend changes are near-zero as well as episodes where expectations became unhinged and trend changes were large. To this end, the random walk disturbances are assumed to have stochastic volatility, with drifting log-variances, adopting the specification used, for example, by Stock and Watson (2007) as well as Cogley and Sargent (2005).

$$\overline{e_t} \sim N(0, \overline{\sigma}_t^2) \qquad \log \overline{\sigma}_t^2 = h_t = h_{t-1} + \sigma_h \xi_t \qquad \xi_t \sim N(0,1) \qquad (1)$$

This trend definition is then embedded into two models of inflation dynamics, which are described next.

Univariate UCSV Model

The UCSV model of Stock and Watson (2007) takes inflation as exhibiting no persistence and that it is also affected by a separate process for stochastic volatility

$$\tilde{\pi}_t \sim N(0, \tilde{\sigma}_t^2) \qquad \log \tilde{\sigma}_t^2 = \tilde{h}_t = \tilde{h}_{t-1} + \sigma_{\tilde{h}} \widetilde{\xi_t} \quad \tilde{\xi}_t \sim N(0,1)$$

Disturbances to trend and cycle, as well as the shocks to stochastic volatility are supposed to be serially and mutually uncorrelated.

Multivariate Model (*MVSV*)

As an alternative to the univariate UCSV model, we also study trend estimates derived from a multivariate model with stochastic volatility (MVSV), which jointly conditions on three inflation measures for each country; a variant of the model has been applied by Mertens (2011) and this study extends this work to international data. Moreover, our model incorporates time-varying volatility in both the trend and the gap component of inflation. The model thus nests the UCSV case. In our application, the model uses observations on inflation in headline CPI, core CPI, and the GDP deflator, stacked into a vector Y_t, and applies a Beveridge-Nelson decomposition, similar to the UCSV model above:

$$Y_t = \tau_t + \tilde{Y}_t \qquad \tau_t = \lim_{k \to \infty} E_t Y_{t+k}$$

The key assumption of the multivariate model is that all variables in $Y_t$share the same common trend and their trend levels differ only up to a constant.[9] Crucially, trend changes in all three inflation measures have the same stochastic volatility behavior as in equation (1) above.

By contrast with the UCSV model, inflation gaps can be persistent in the multivariate model, provided they remain stationary. Specifically, the inflation gaps follow a stationary VAR with constant parameters and constant correlations and a common volatility factor:

$$A(L)\tilde{Y}_t = \tilde{e}_t \qquad \tilde{e}_t \sim N(0, \tilde{\sigma}_t^2\, \Sigma)$$

The time-varying scale factor of the gap shocks is assumed to follow the same process as in the UCSV model; a random walk without drift in the log of $\tilde{\sigma}_t^2$. This approach has been proposed by Carriero et al (2012), in the context of VARs applied to observable data instead of our inflation gaps. These authors report considerable gains—not only in computational efficiency but also model fit and forecast accuracy—from restricting the number of time-varying volatility factors this way, as opposed to assuming separate sources of stochastic volatility for each variable. In our application, such a more general specification even proved hard to implement, with at times hardly plausible results, likely due to the VAR being applied to the latent gap factors (as opposed to observable data), and the presence of missing data for several inflation series in many countries.

The roots of the VAR polynomial $A(L)$ are required to lie outside the unit circle, to ensure that the gaps are stationary. Shocks to gaps and trend are assumed to be mutually uncorrelated.[10] Apart from requiring the volatility of gap shocks to be constant, the multivariate thus nests the UCSV model, while extending it to multiple input series and persistent gap dynamics. Choosing to model gap dynamics as being time-invariant enables the model to better handle our data set where data for some inflation measures is partly missing, than what would be possible when gap dynamics were time-varying.

Missing observations in Y_t are easily handled, by casting the model in state space form with (deterministic) time-variation in measurement loadings. In the case of missing observations, the

[9] The average trend levels are allowed to differ to reflect different average levels for the various inflation series.
[10] Mertens (2011) allows shocks to trend and gaps to be correlated. For simplicity, however, orthogonality is imposed here; in particular since for some countries the implied assumption of time-varying trend volatility but constant correlation between shocks to trend and gaps made the model hard to estimate.

appropriate elements of Y_t are encoded as zeros and so are their loadings on the model's states; see for example Mertens (2011) for details.

Estimation methods

The models are estimated with Markov-Chain Monte Carlo methods, as described in Mertens (2011). The algorithm yields not only estimates of the latent factors The sampling algorithm recovers the posterior distribution of missing data entries, conditional on the model and all observed data values. Convergence is assessed with scale reduction tests, applied to the output of multiple chains that started from dispersed initial conditions.

4. Inflation Trends: Levels and Uncertainty

This section reports country-by-country estimates of inflation trends and gaps as well as their time-varying variability, generated from the UCSV model of Stock and Watson (2007) and our MVSV model. The UCSV estimates complement and extend the results reported by Cecchetti, Hooper, Kasman, Schoenholtz, and Watson (2007), whose estimates are conditioned on the GDP deflators for the G7 countries. The UCSV estimates reported below are conditioned on CPI inflation (headline). For ease of comparison, we also report only the gap estimates of CPI (headline) inflation for the MVSV model.[11] The estimates reported below are conditioned on all available data since 1960, except for the removal of certain dates, listed in Table 2, when price shifts occurred. The nature of these price shifts and their effect on our estimates are discussed in Section 5.

[Figures 1–14 about here]

Comparing estimates from the UCSV model and the MVSV for each country, there are some broad similarities, but also notable differences. Estimates from both models capture very similar low-frequency movements. But, typically, the trend estimates from the UCSV model are more variable, and comove more strongly with the actual data, while the gap estimates of the UCSV model are much less persistent. Compared with the MVSV estimates, the UCSV trend estimates appear to overstate changes in trend inflation by several percentage points. Similarly, there are marked differences in the stochastic volatility estimates from both models. While estimates from both models typically find a decline in trend volatility over the postwar sample, the UCSV estimates typically suggest a much larger degree of unanchored inflation expectations in the 1970s, while MVSV estimates of trend volatility display a much milder hump shape, if not a mere gradual decline in most countries. Strikingly, much of the time variation in UCSV estimates of trend volatility seems to be captured by time-variation in the MVSV estimates of gap volatility.

Several countries, listed in the lower panel of Table 1, have introduced formal inflation goals during the sample period. In most cases, estimated trend levels from both models tend to hover around these goals. Interestingly, our measure of anchored inflation expectations—the stochastic volatility of trend shocks—tends to decrease only within about five to ten years in most cases.

We defer a detailed description of our country-by-country results for the next revision of this draft. However, a few country-specific observations are worth mentioning already: Amidst the countries with explicit inflation goals, the trend estimates for Sweden, shown in Panels (a) and (b) of Figure 11, stand out by almost permanently hovering about half a percentage point below the Riksbank's inflation target of 2%; Svensson (2013) has noted the same phenomenon and discusses potential implications.

[11] Gap estimates for core CPI and the GDP deflator will be provided in a separate appendix.

Not surprisingly either, the estimated trend levels for Japan, shown in Figure 8, are amongst the lowest in our cross-country sample. Both MVSV and UCSV estimates put Japanese trend inflation at levels below zero for the last decade and in particular the 90% credible sets of the MVSV model barely cover any positive values over that period. Concerns about rising deflation risks are also raised by our trend estimates for Switzerland, shown in Figure 12, which are clearly drifting down towards zero over the last few years, having remained stable near two percent for most of the last 15 years.

An interesting comparison between the MVSV and UCSV estimates is offered by the case of the UK, estimates for which are displayed in 13. Over recent years, U.K. inflation has been persistently running above the Bank of England's 2% target, and these overshoots have some influence on our estimates. In particular, the UCSV estimates are increasing over the last five years, up to levels near 4%. In contrast, the MVSV model generates a more cautious increase in trend inflation for the United Kingdom because of persistence embedded into the model specification of gap dynamics.

5. The Effects of Price Shift Dates on Trend Estimates

The estimates presented in the previous section are conditioned on all available data in our sample, except for the removal of country-specific dates on which price shifts occurred due to non-market factors.[12] The results shown in Figures 1 to 14 were generated from inflation data for which periods of price shifts are treated as missing values in each model's estimation. The relevance of these episodes for our estimates, including a comparison with estimates conditional on all data, is the subject of this section.

All in all, we consider 15 price shift episodes affecting 7 out of the 14 countries in our sample; all are listed in Table 2. Most episodes are related to increases in taxes on goods and services and similar administrative surcharges, thus removing only a single quarterly observation from the data. The rationale for omitting these specific dates is that the price level shifted in the period in question not as a reflection of monetary policy or of private sector-initiated behavior, but because of a nonmonetary governmental measure whose effect was essentially to rescale the price level. Only three episodes were somewhat longer: The price controls in the U.S. (1971/74) and New Zealand (1982/84) as well as the transition period in the wake of German reunification (1991). Again, the shift in the price level in these dates corresponded either to a movement away from market determination of prices (in the case of the price control episodes) or a major redefinition of the area covered by the price index (as when the former East Germany was brought into the Federal Republic of Germany).[13]

[Figure 15 about here]

Reflecting their short duration, the price shift dates leave not much impact on trend estimates for many countries. But this is not invariably the case. Figure 15 presents trend estimates for four countries, German, Ireland, New Zealand and the U.S., for which the inclusion of price shift dates has nonnegligible effect on trend estimates, at least when using the UCSV model. The figure compares the trend estimates discussed in the previous section against estimates that condition on the entire data, including inflation data recorded during the price shift episodes. For each country, trend estimates from the MVSV around the price shift dates are not much affected whether the price shift data is included or excluded from the estimation. In the case of the UCSV estimates, there are however sizable differences. For example, the UCSV estimate of trend inflation in the U.S. peaks above 10% in the mid-1970s, when conditioned on the full data, whereas in the case where the price shifts are treated as missing data, the estimated inflation trend rises only gradually from about 5 to 8 percent during the same period.

[12] Inflation data for periods of price shifts are treated as missing values in the estimation of those results.

[13] Gordon (1983) and Staiger, Stock, and Watson (1997) are previous studies that allowed for the effects of price controls in their study of inflation dynamics, while Levin and Piger (2002) allow for major changes in national sales taxes. In addition, the exclusion of control and tax periods from the estimates represents a step in the direction of incorporating historical information about individual countries' experiences into the study of inflation dynamics, as recommended by ecchetti, Hooper, Kasman, Schoenholtz, and Watson (2007).

Also, the estimated gap volatilities from the UCSV model prove to be more sensitive to the inclusion of price shift dates in the case of the U.S., and similarly so for New Zealand, see Panel (h) of Figures 9 and 14. In both cases, UCSV estimates of the gap levels right before and after the price shift periods are quite elevated, consistent with a rise in volatility. When the price shifts are treated as missing data, the Random Walk assumption then causes the estimated volatilities to remain elevated throughout the price shift period, whereas these patterns is somewhat mollified when all data are included (results not shown here).

Detailed results for each country, with and without price shift dates are provided in Figure 16 (for the MVSV model) and Figure 17 (for the UCSV model).

[Figures 16–17 about here]

6. Conclusion

Our paper compares estimates of trend inflation in fourteen advanced economies using two different models. Our preferred model is a multivariate extension to Stock and Watson's (2007) the unobserved components model with stochastic volatility (UCSV) that has been applied to the G7 countries by Cecchetti, Hooper, Kasman, Schoenholtz, and Watson (2007). Like the UCSV model, our multivariate stochastic volatility model (MVSV) tracks time-variation in the variability of shocks to trend inflation and inflation gap. But as in the model of Mertens (2011), gap estimates from our model display persistence, while the UCSV model embeds the assumption that gaps are serially uncorrelated. The MVSV trends are consequently smoother and less variable, since the underlying filtering procedure exhibits less leakage from persistent components of the data, which do not prove to be permanent. Thus, the MVSV estimates are less influenced by the occurrence of country-specific episodes in which price levels shifted because of non-market factors, like tax changes.

In addition, the MVSV model conditions on multiple inflation series, assuming they share a common trend. In contrast to Cogley and Sargent (2005) and Cogley, Primiceri, and Sargent (2010), our model restricts time-variation in its parameters only to stochastic volatility, and to have only two sources: drift in the log-variances of shocks to the common trend and a common scale factor to all gaps. Limiting the amount of time-varying parameters makes the model more tractable, and it also enables us to handle missing data in some of the inflation series for several countries. This approach also promises better forecast accuracy, which is a subject of our ongoing research.

While our estimates of trend inflation display quite some similarities across countries—notably the shared experiences of persistently elevated inflation rates in the 1970s and more stably-anchored inflation expectations over the last two decades—there are also clear differences in the trend estimates. For example, the extent to which trend inflation rose and fell over the postwar sample differs markedly. Also, for many countries, distinct, country-specific changes in monetary regime, like the adoption of a formal inflation target, are clearly visible in the trend estimates.

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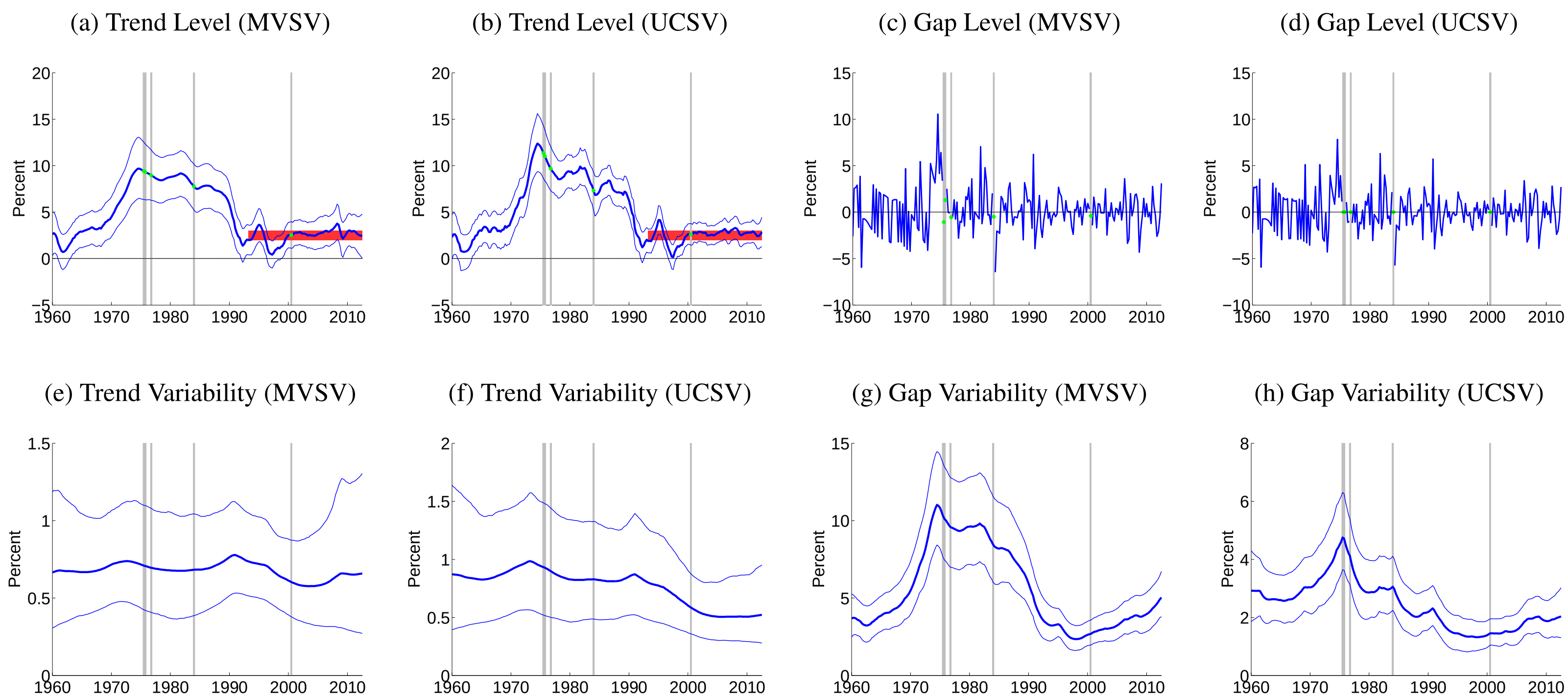
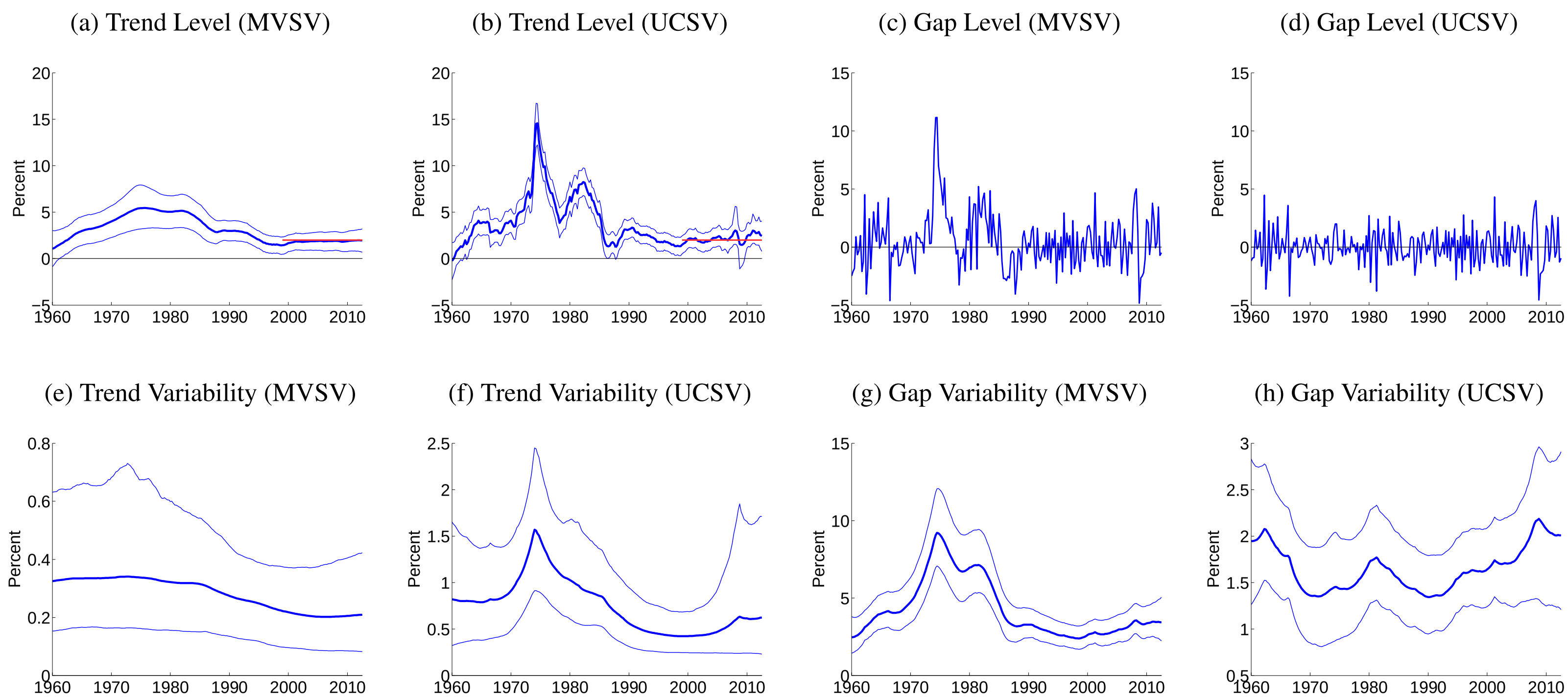
Figure 1: Australia



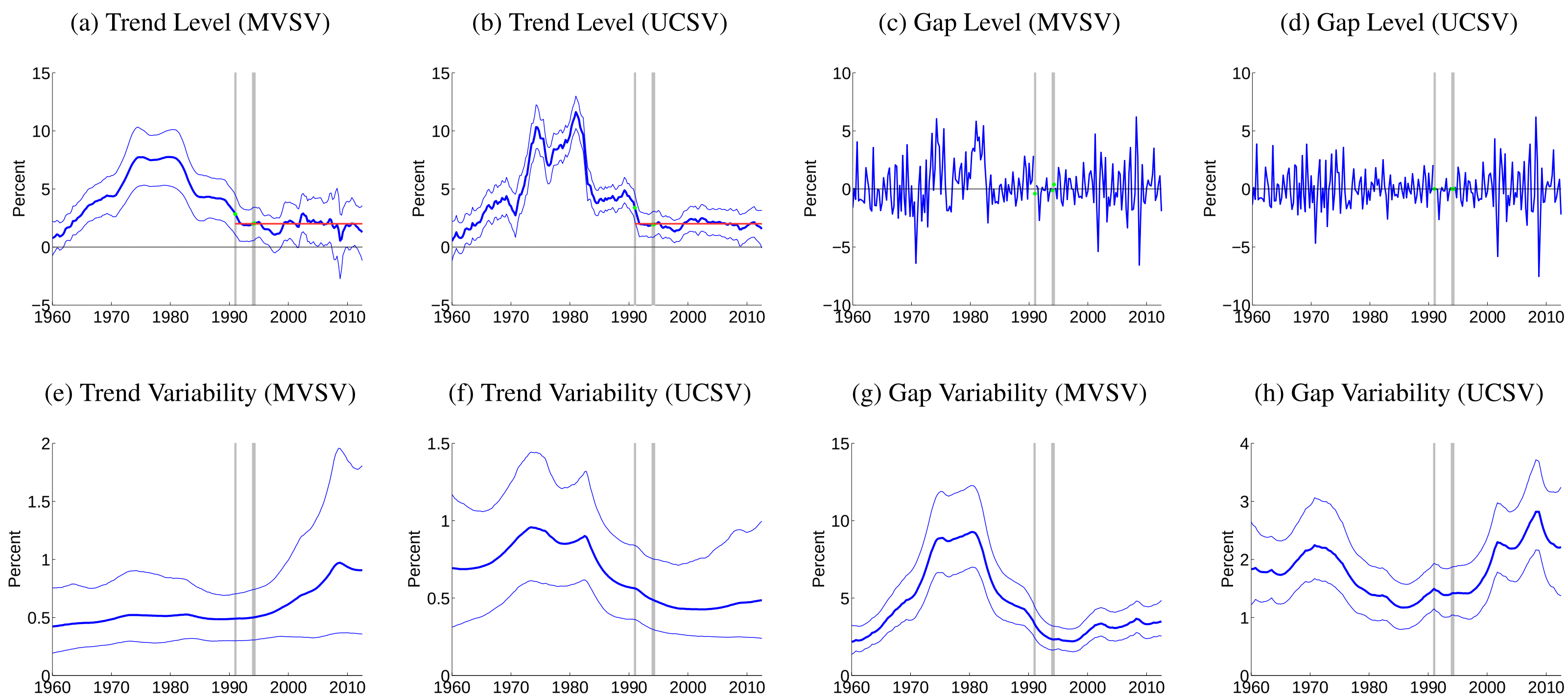
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the range of an offically stated inflation goal.

Figure 2: Belgium



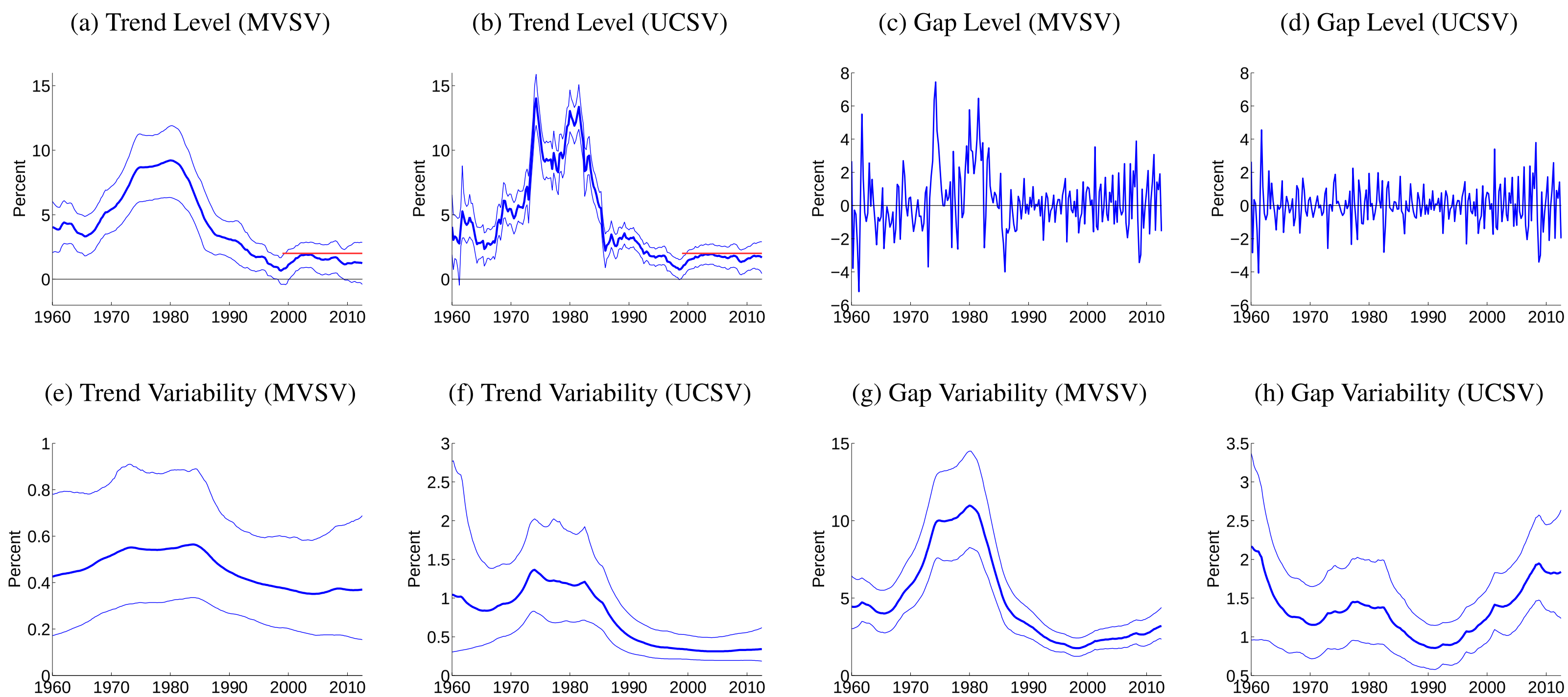
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 3: Canada



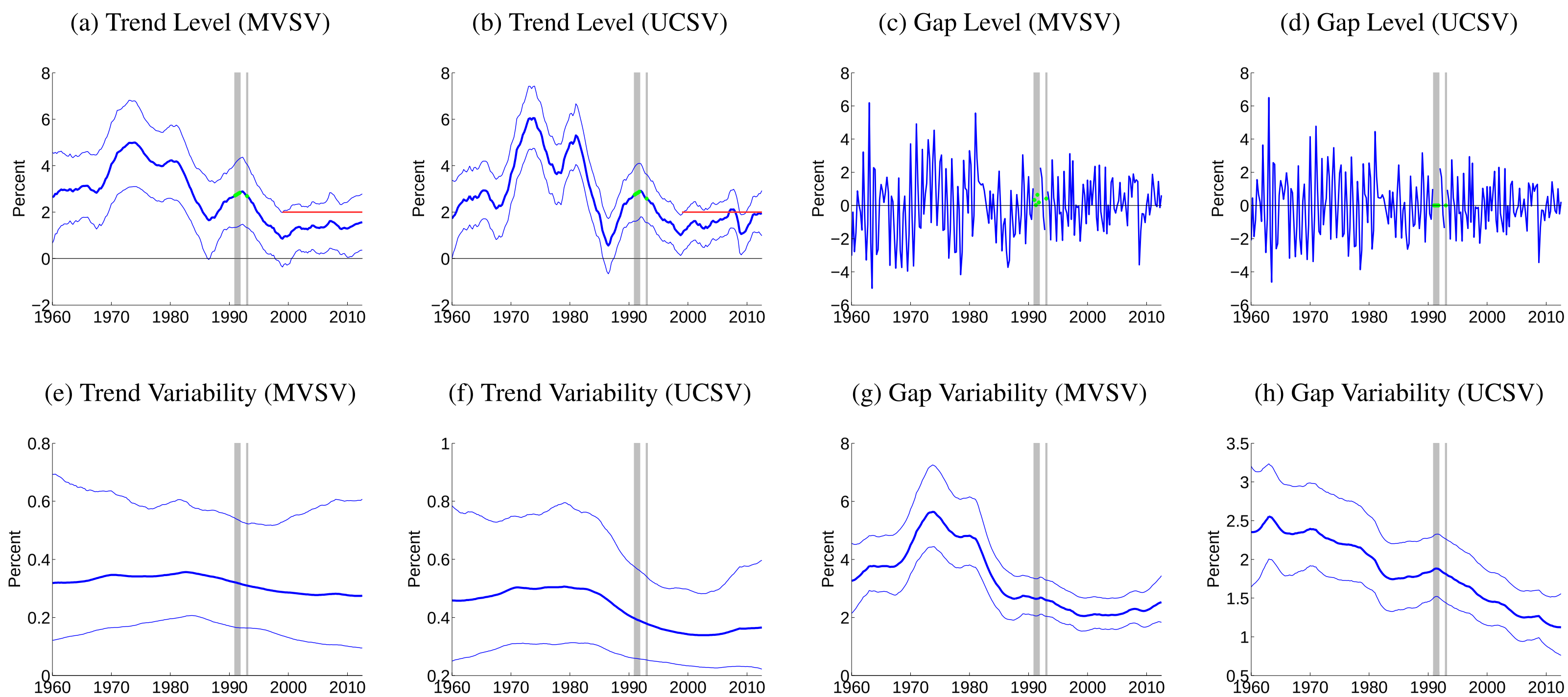
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 4: France



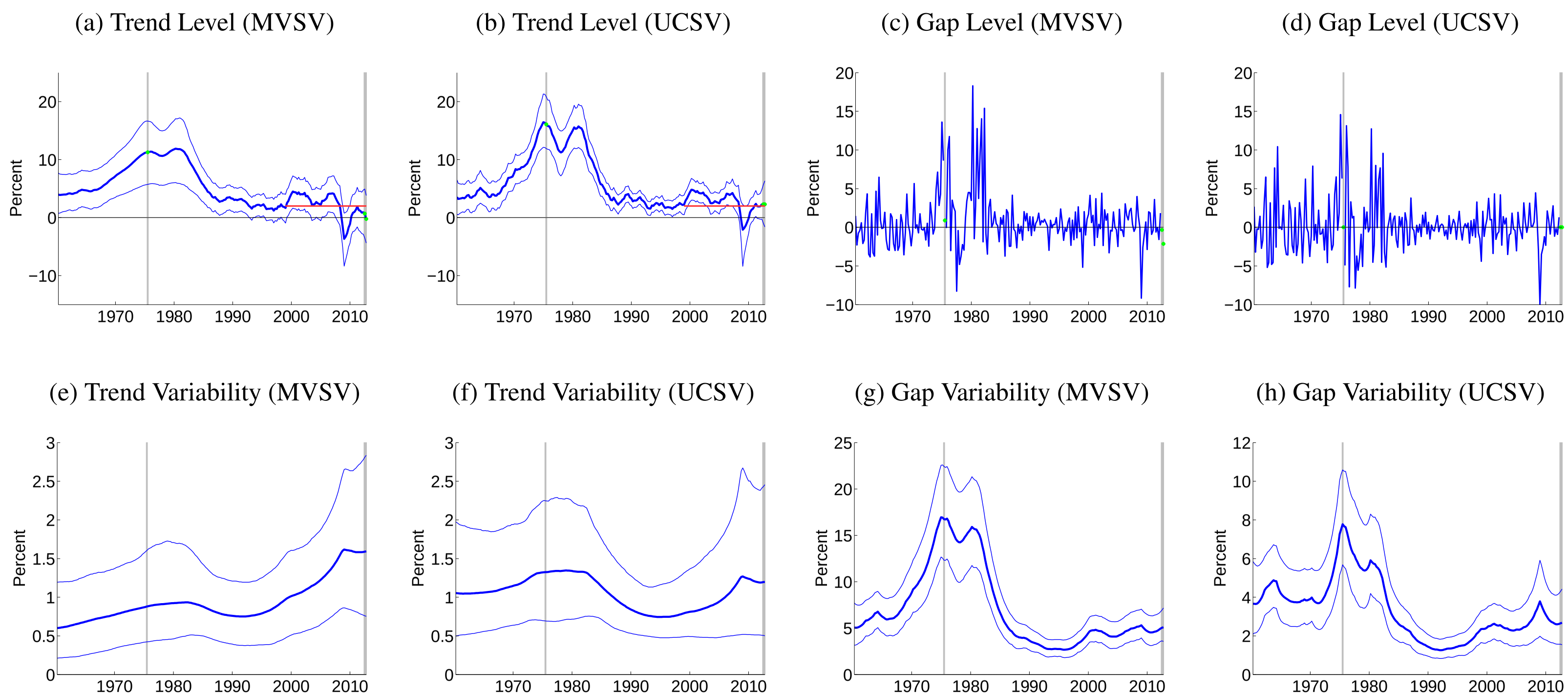
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 5: Germany



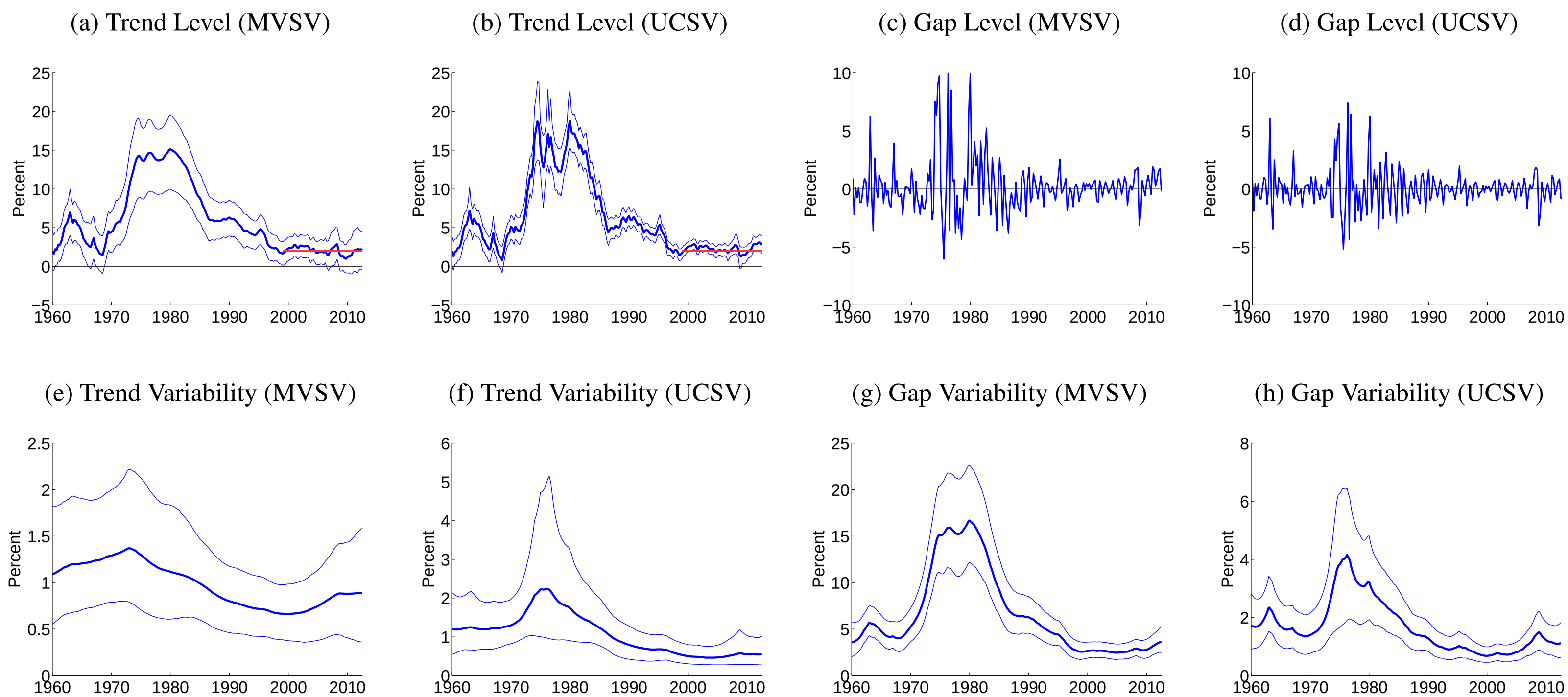
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 6: Ireland



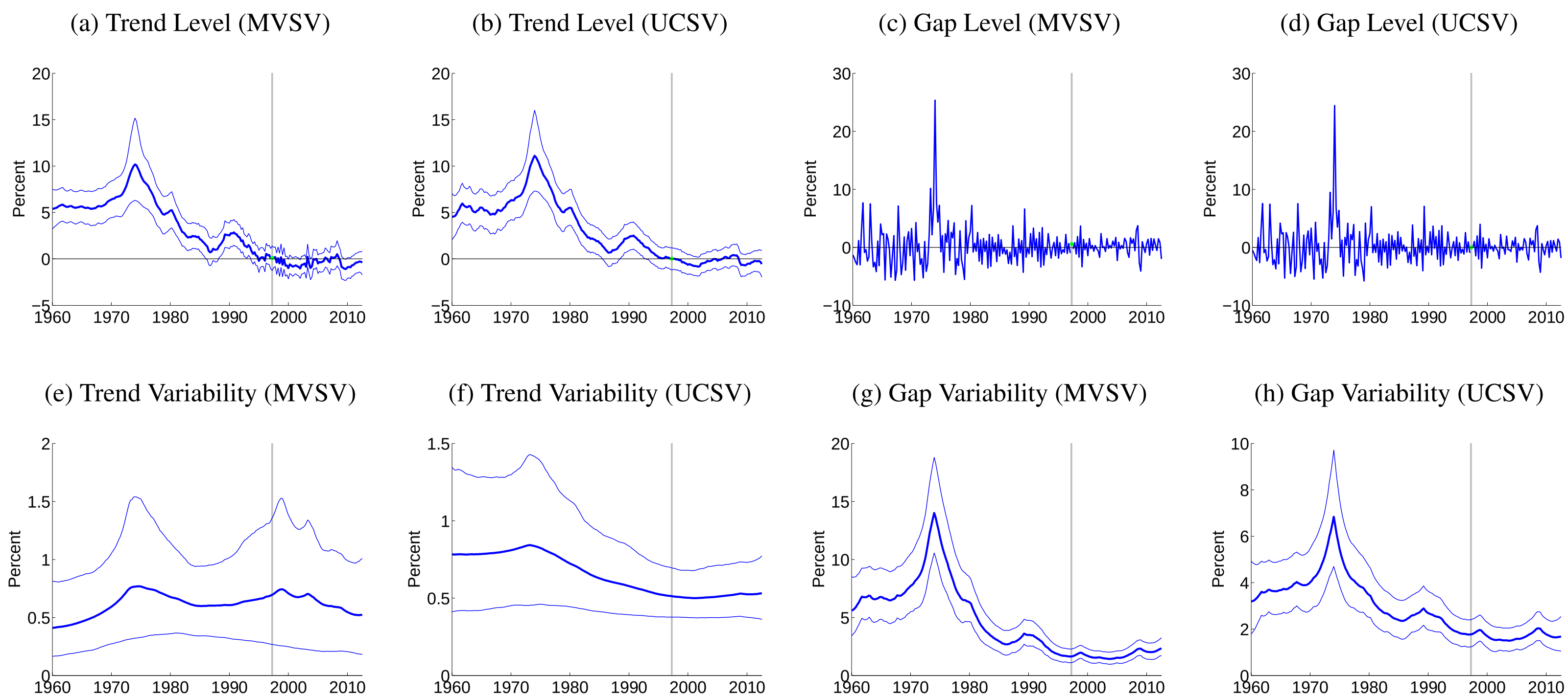
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 7: Italy



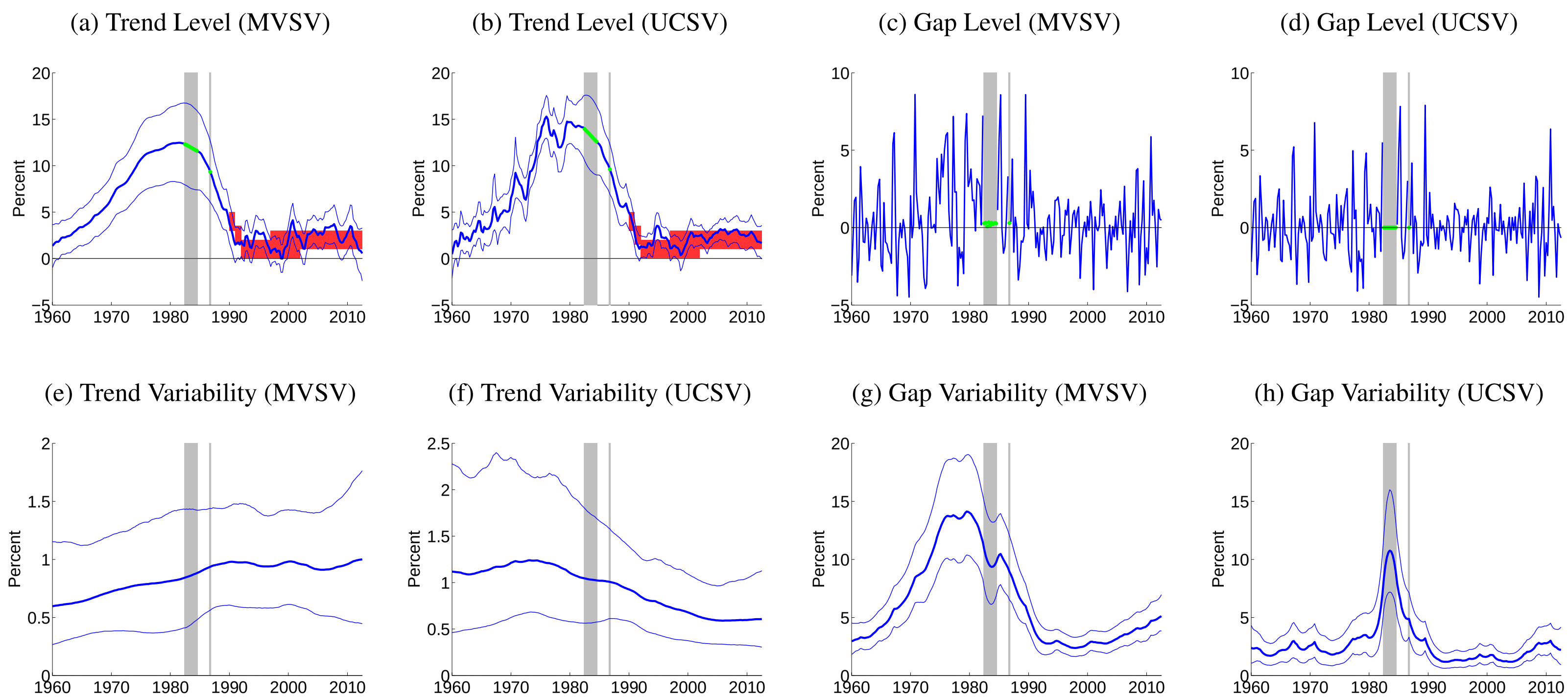
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 8: Japan



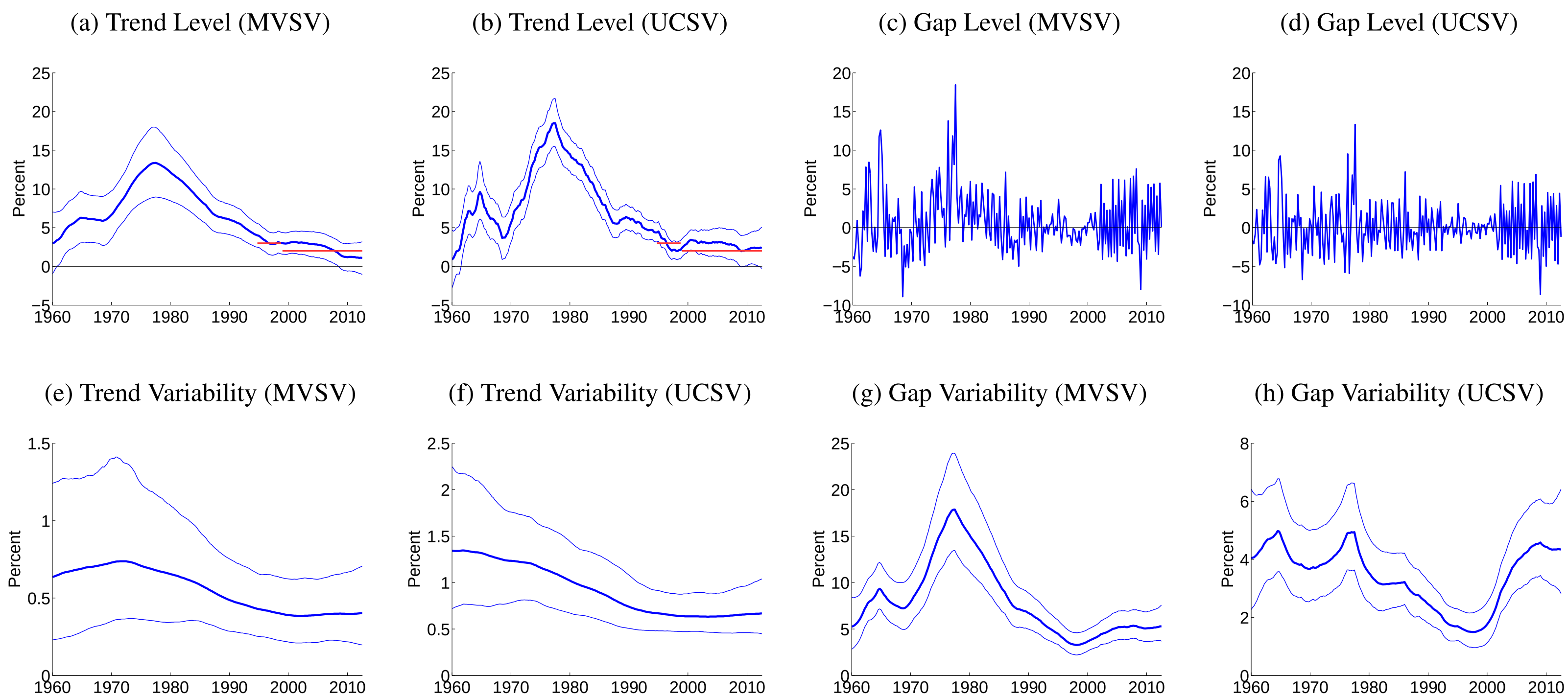
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b).

Figure 9: New Zealand



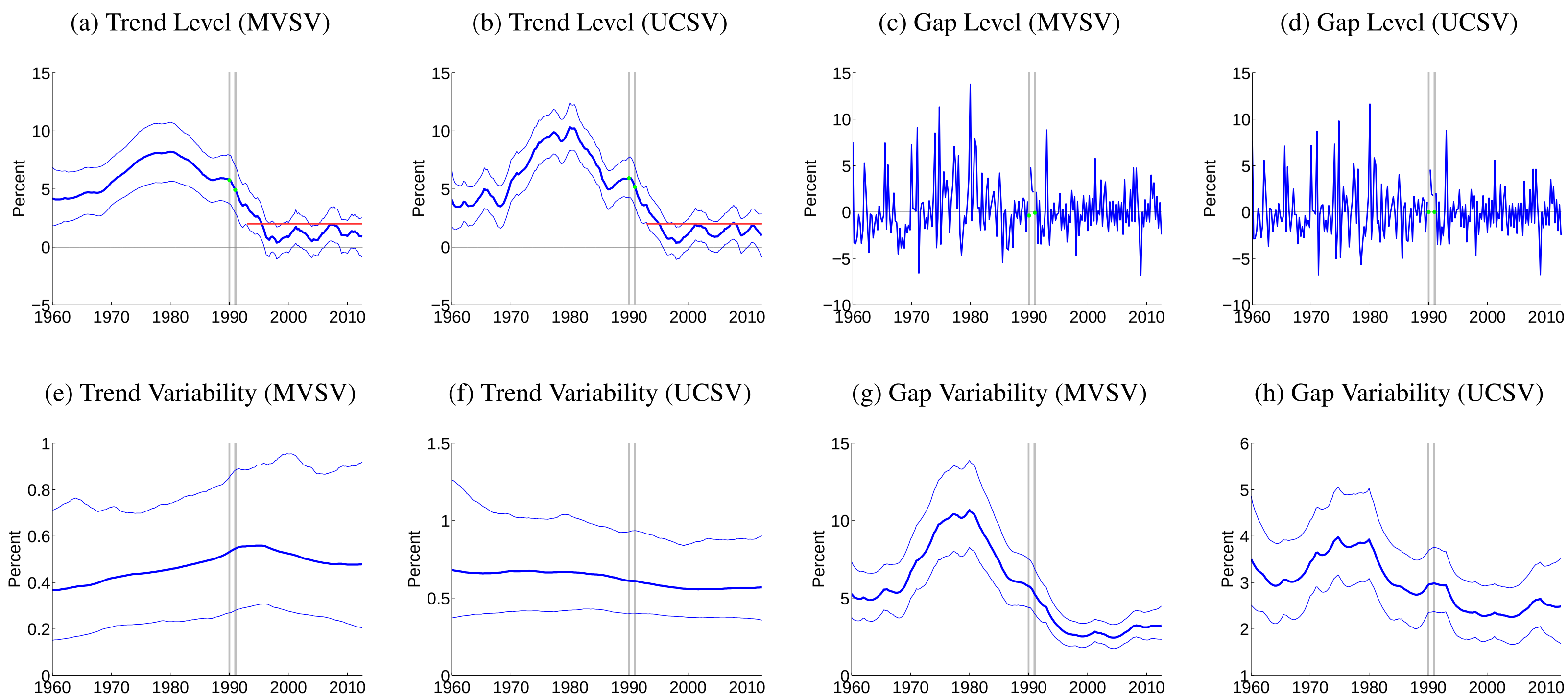
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the range of an offically stated inflation goal.

Figure 10: Spain



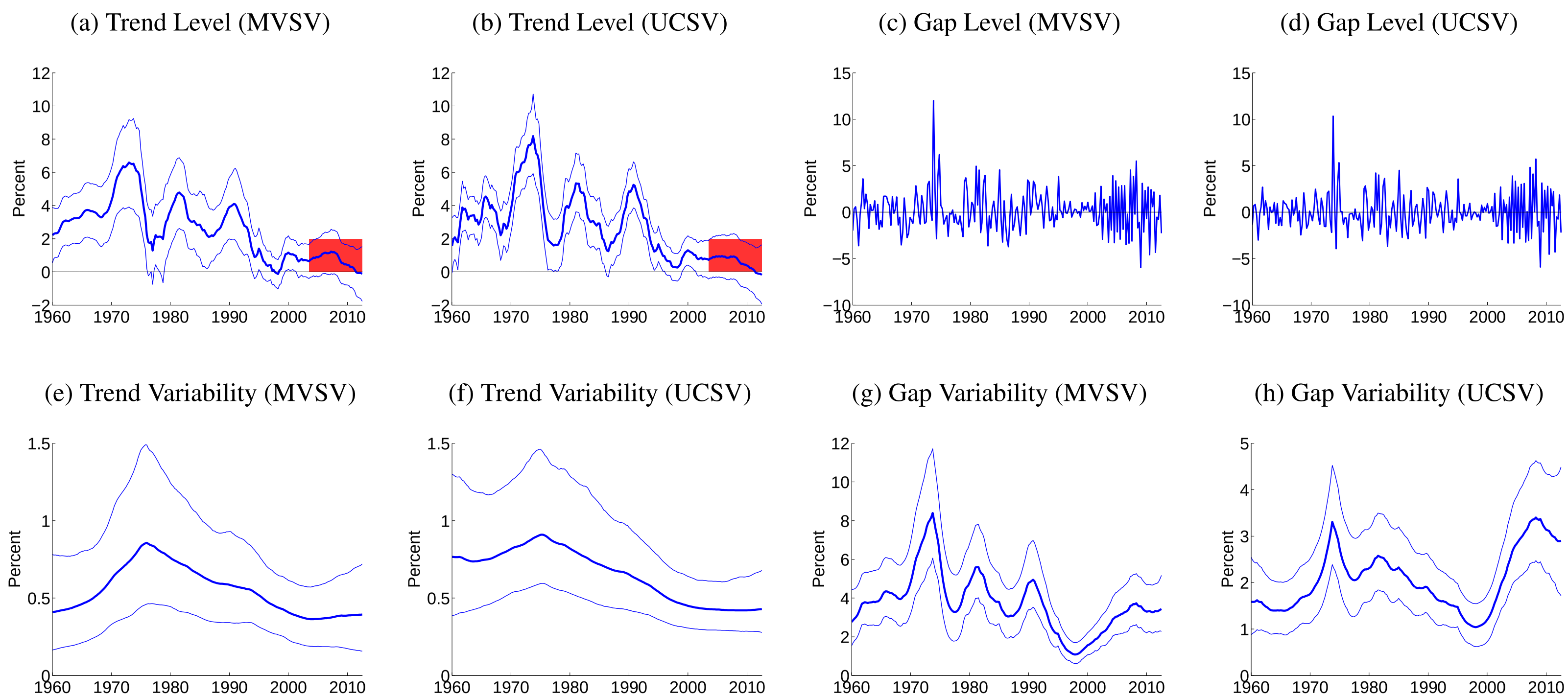
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 11: Sweden



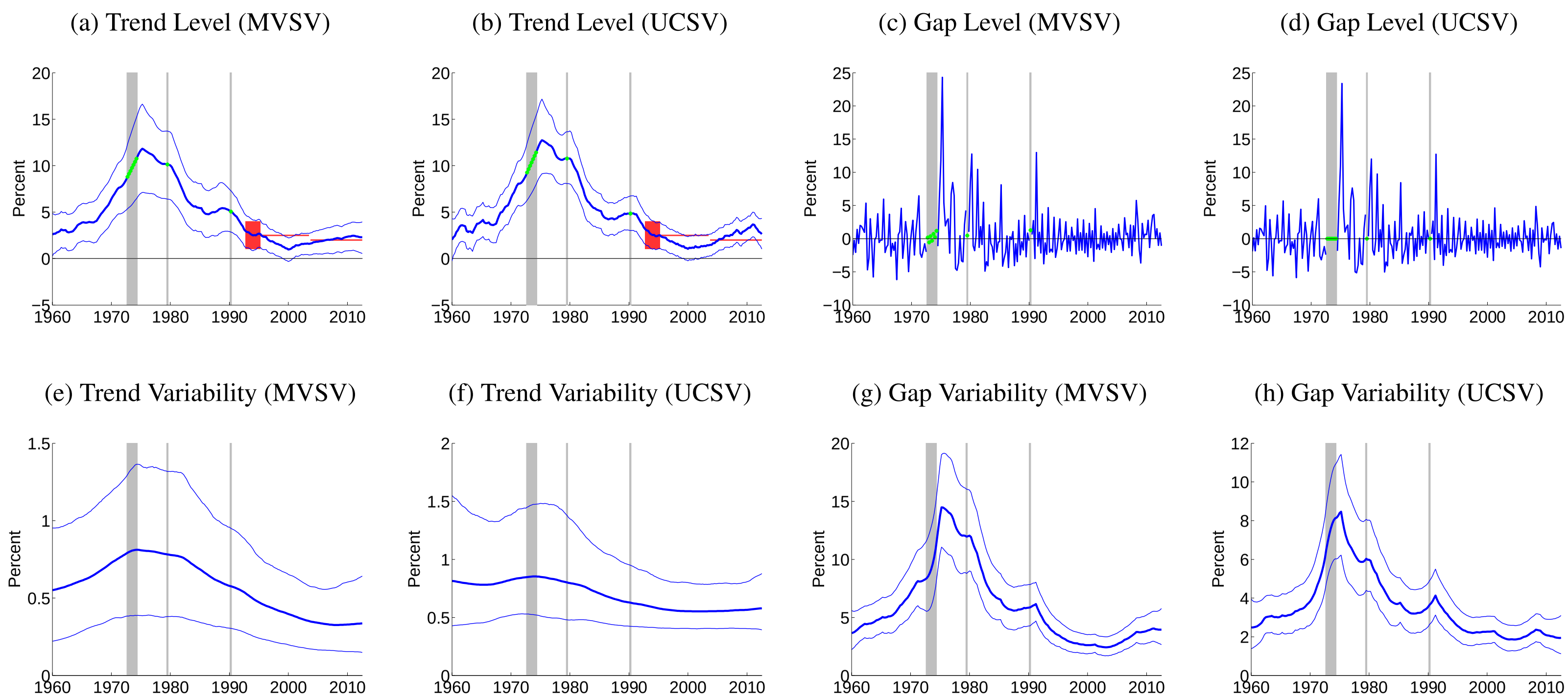
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 12: Switzerland



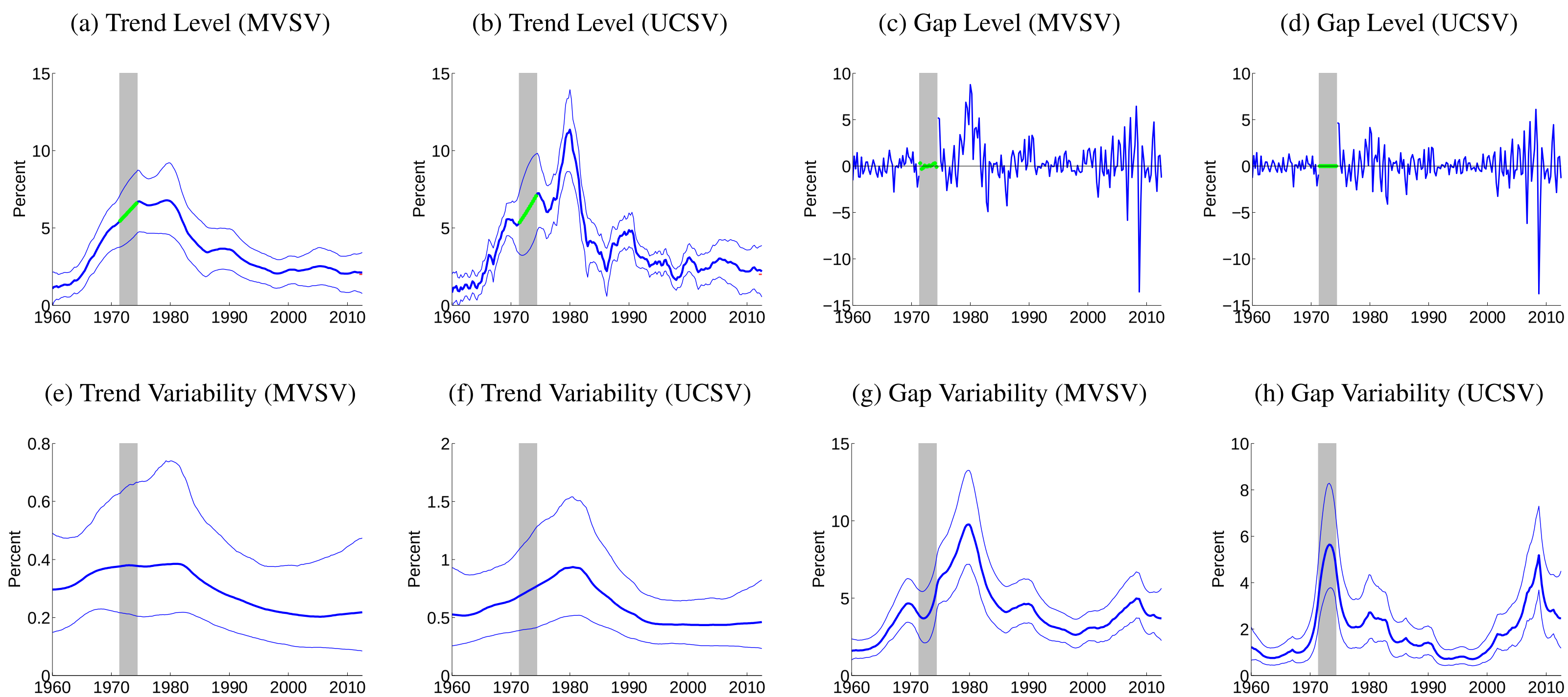
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. In Panels (a) and (b), the solid red line marks the range of an offically stated inflation goal.

Figure 13: United Kingdom



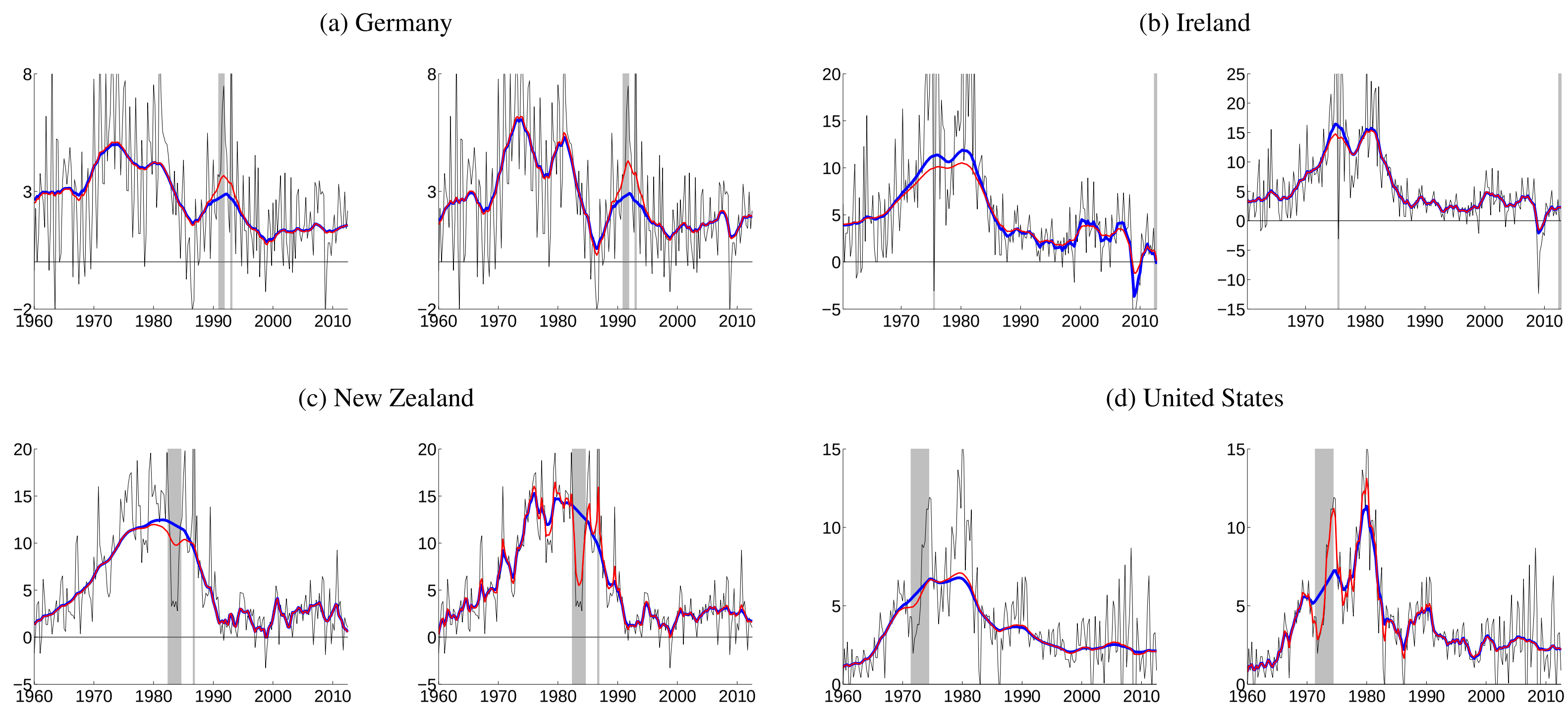
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b). In Panels (a) and (b), the solid red line marks the level of an offically stated inflation goal.

Figure 14: United States



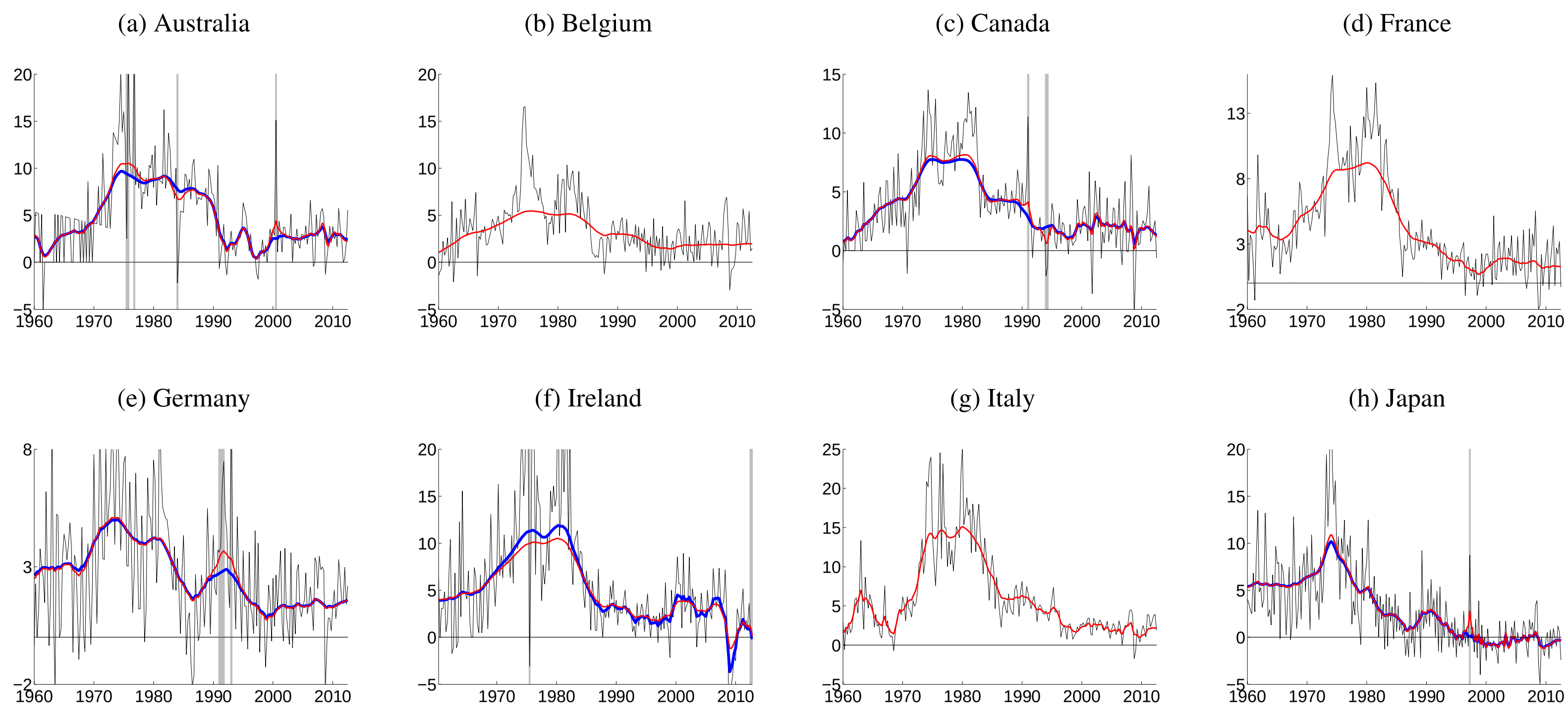
Note: Solid, thick blue lines show posterior means, and thinner blue lines depict 90% confidence sets derived from the model's posterior distribution conditional on all data. All levels are measured in annualized percentage points. Uncertainty is measured by the standard deviation of a quarterly trend shock. Data sources as listed in Table 1, using all available data since 1960. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. For those periods, estimated inflation gaps, shown in Panels (c) and (d), are marked green. When there are no price shift dates, the gap estimates are identical to the difference between actual inflation and the trend estimates, shown in Panels (a) and (b).

Figure 15: Trend Estimates and Price Shift Dates



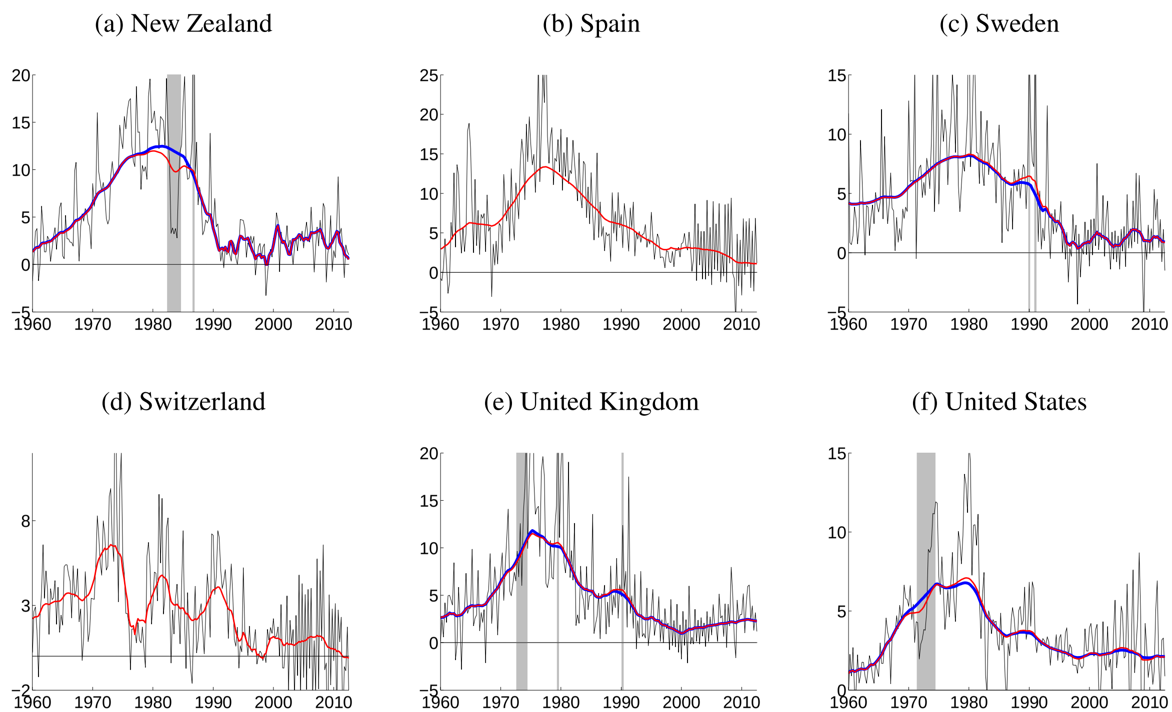
Note: In each panel, the left-hand side picture shows results from the MVSV model, the right-hand side picture has been generated from the UCSV model. Grey shading marks dates in which data was excluded from computation due to shifts in the price index at that time. All country specific price shift dates for input measures are listed in Table 2. Thin lines denote the actual data for inflation the headline CPI index. All levels are measured in annualized percentage points.

Figure 16a: Trend Estimates for MVSV Model



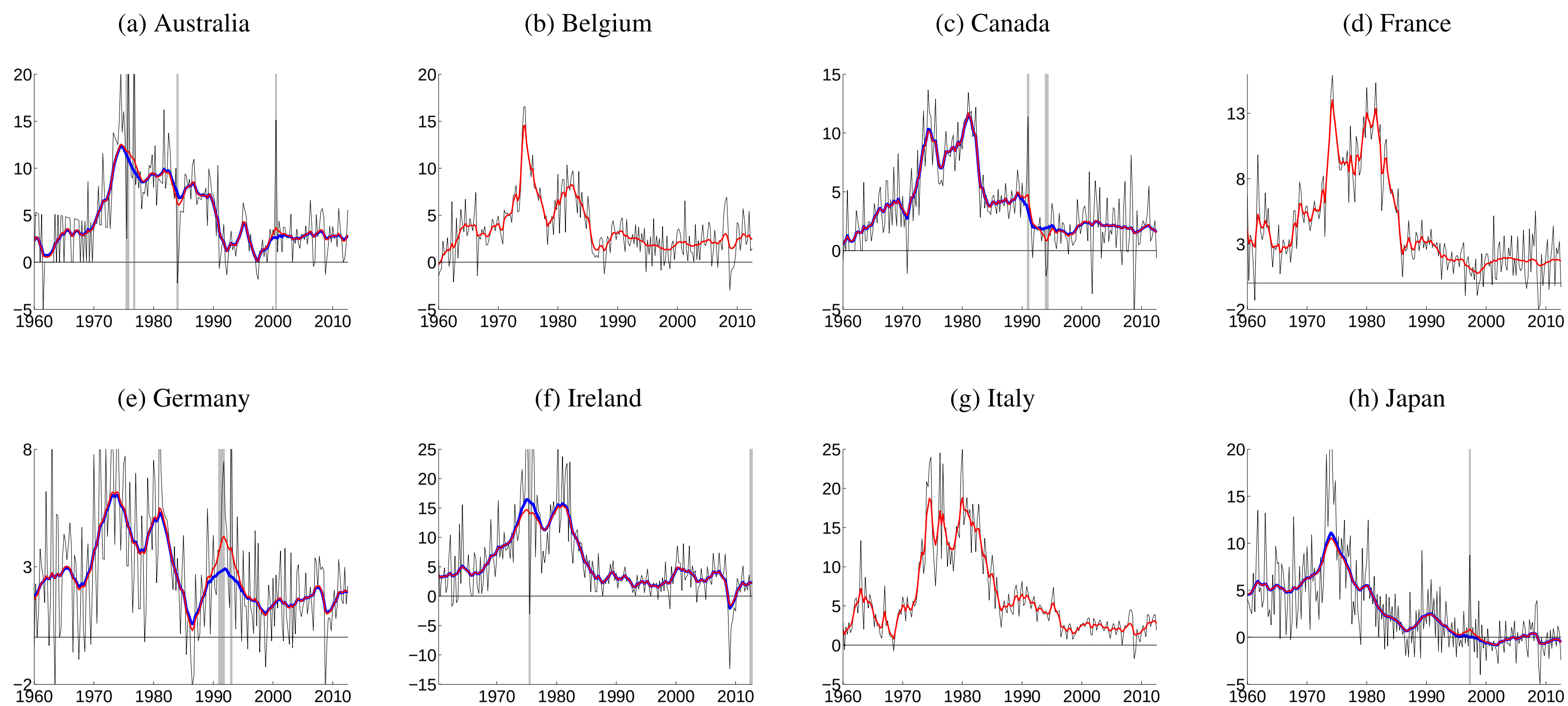
Note: Headline CPI inflation is shown in black, with the trend estimate including shift price dates in red. The trend estimate omitting price shift dates is shown in blue, with grey shading to indicate the specific time horizon (see Table 2).

Figure 16b: Trend Estimates for MVSV Model



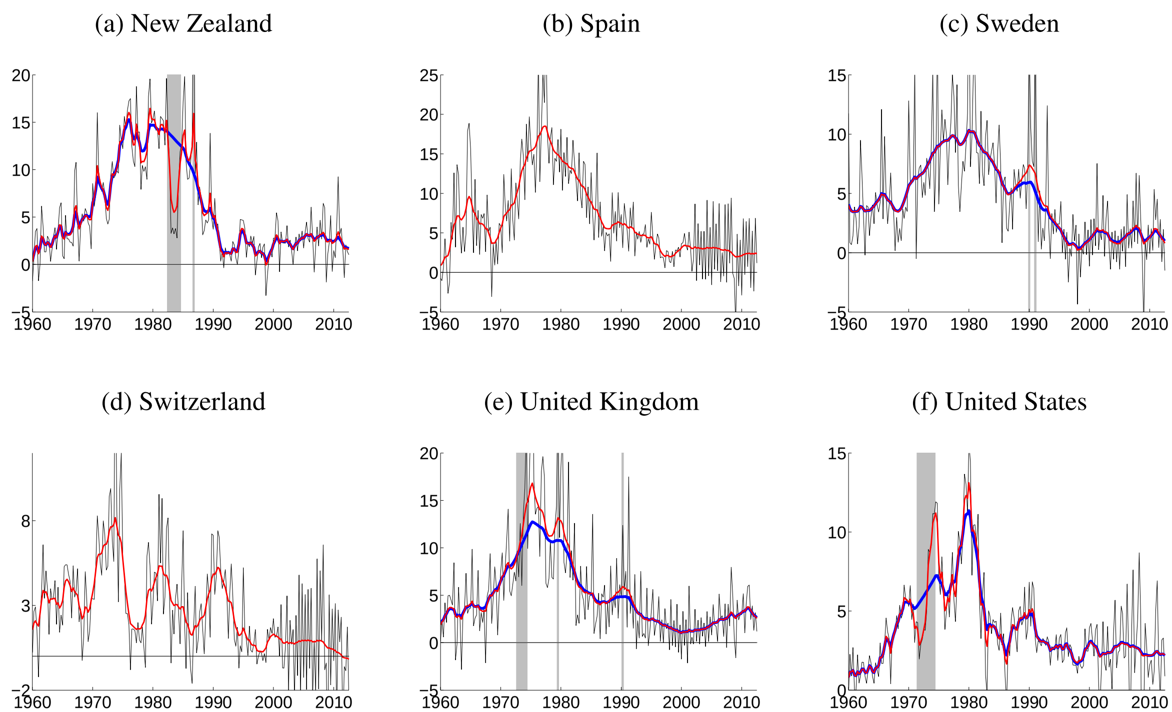
Note: Headline CPI inflation is shown in black, with the trend estimate including shift price dates in red. The trend estimate omitting price shift dates is shown in blue, with grey shading to indicate the specific time horizon (see Table 2).

Figure 17a: Trend Estimates for UCSV Model



Note: Headline CPI inflation is shown in black, with the trend estimate including shift price dates in red. The trend estimate omitting price shift dates is shown in blue, with grey shading to indicate the specific time horizon (see Table 2).

Figure 17b: Trend Estimates for UCSV Model



Note: Headline CPI inflation is shown in black, with the trend estimate including shift price dates in red. The trend estimate omitting price shift dates is shown in blue, with grey shading to indicate the specific time horizon (see Table 2).

Table 1: Data Overview

Inflation Rates				
Country		Headline CPI	Core CPI	GDP Deflator*
AL:	Australia	1960Q1	1976Q3	1960Q1
BE:	Belgium	1960Q1	1976Q1	1980Q1
CA:	Canada	1960Q1	1961Q1	1960Q1
FR:	France	1960Q1	1960Q1	1960Q1
GE:	Germany	1960Q1	1962Q1	1960Q1
IR:	Ireland	1960Q2	1976Q1	
IT:	Italy	1960Q1	1960Q1	1960Q1
JA:	Japan	1960Q1	1970Q1	1960Q1
NZ:	New Zealand	1960Q1	1969Q1	1981Q2
SP:	Spain	1960Q1	1976Q1	1970Q1
SW:	Sweden	1960Q1	1970Q1	1980Q1
SZ:	Switzerland	1960Q1	1960Q1	1970Q1
UK:	United Kingdom	1960Q1	1970Q1	1960Q1
US:	United States	1960Q1	1960Q1	1960Q1

Inflation Goals		
Country	Inflation Goal	Dates
Australia	2.0 – 3.0	1993Q2 :: Present
Canada	2.0	1991Q1 :: Present
Eurozone*	2.0	1998Q2 :: Present
New Zealand	3.0 – 5.0	1990Q1 :: 1990Q4
	1.5 – 3.5	1991Q1 :: 1991Q4
	0.0 – 2.0	1992Q1 :: 1996Q4
	0.0 – 3.0	1997Q1 :: 2001Q4
	1.0 – 3.0	2002Q1 :: Present
Spain	3.0	1994Q4 :: 1998Q4
Sweden	2.0 ± 1	1993Q1 :: Present
Switzerland	<2.0	2003Q3 :: Present
United Kingdom	1.0 – 4.0	1992Q4 :: 1995Q1
	2.5	1995Q2 :: 2003Q3
	2.0	2003Q4 :: Present

Note: The model uses quarterly observations from 1960Q1 through 2012Q3. All variables are annualized and expressed in logs. Section 2 provides more information on the data sources.

* Belgium, France, Germany, Ireland, Italy, and Spain have all been Eurozone countries since the currency area's inception.

Table 2: Omitted Price Shift Dates

Inflation Rates		
Country	Date	Event
Australia	1975Q3	Universal health insurance
	1975Q4	Sales tax increase
	1976Q4	Universal health insurance
	1984Q1	Medicare introduction
	2000Q3	GST introduction
Canada	1991Q1	GST introduction
	1994Q1 – 1994Q2	Cigarette tax change
Germany	1991Q1 – 1991Q4	Reunification
	1993Q1	VAT increase
Ireland	1975Q3	Indirect tax cut
Japan	1997Q2	Consumption tax increase
New Zealand	1982Q3 – 1984Q3	Price controls
	1986Q4	GST introduction
Sweden	1990Q1	VAT increase
	1991Q1	VAT increase
United Kingdom	1972Q4 – 1974Q2	Price Controls
	1979Q3	Indirect tax increase
	1990Q2	Poll tax introduction
United States	1971Q3 – 1974Q2	Nixon price controls