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ABSTRACT

Evolving International Inflation Dynamics: Evidence from a Time-varying Dynamic Factor Model*

Several industrialised countries have had a similar inflation experience in the past 30 years, with inflation high and volatile in the 1970s and the 1980s but low and stable in the most recent period. We explore the dynamics of inflation in these countries via a time-varying factor model. This statistical model is used to describe movements in inflation that are idiosyncratic or country specific and those that are common across countries. In addition, we investigate how comovement has varied across the sample period.

Our results indicate that there has been a decline in the level, persistence and volatility of inflation across our sample of industrialised countries. In addition, there has been a change in the degree of comovement, with the level and persistence of national inflation rates moving more closely together since the mid-1980s.

JEL Classification: E30 and E52
Keywords: factor model, low inflation, monetary policy and time variation

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Summary

Several industrialised countries have had a similar inflation experience over the past 30 years: inflation was typically high and volatile during the second half of the 1970s and the first half of the 1980s but low and stable in the most recent period. National inflation rates have moved together for most of the sample with the notable exception of the years between 1975 and 1987. These observations suggest the following question: how has comovement of inflation rates evolved over time?

This paper uses a statistical model to describe the comovement in inflation across countries and to investigate if the degree of comovement has changed across time. Our estimates suggest that there was a significant decline in the level, persistence and volatility of inflation across our sample of countries. We find that this historical decline in the level and persistence of inflation was common across most G7 countries, Australia, New Zealand and Spain – ie this decline coincided with an increase in comovement in inflation rates as identified by our statistical model.

To interpret further our results, we discuss a number of possible reasons behind the decline in the level and persistence of inflation and the increase in comovement of inflation. Candidate explanations of the former include: an improvement in monetary policy; an improvement in fiscal policy; an increase in productivity and the onset of globalisation. The increase in comovement may be the result of a change in the practice of monetary policy that occurred over a similar period in most countries in our sample and/or the onset of globalisation.

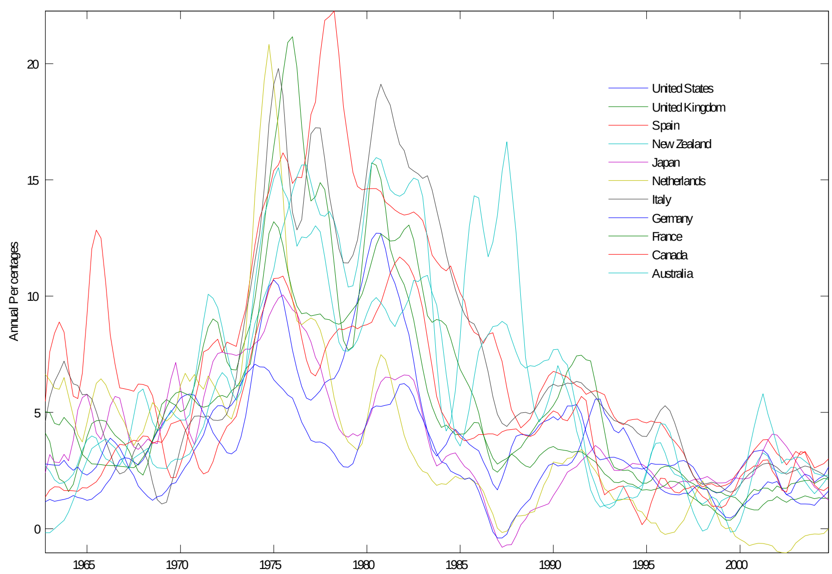
1 Introduction

Many industrialised countries around the world have shared a similar inflation experience over the past 30 years. Inflation was typically high and volatile during the second half of the 1970s and the first half of the 1980s but low and stable in the most recent period. This pattern is apparent in Chart 1, which plots the inflation rates of eleven developed economies. Two features of the chart are worth emphasising. First, national inflation rates moved together for most of the sample. Second, the 1975 to 1987 period was quite different from the rest of the sample. Chart 1 suggests a few questions. What are the common features of movements in national inflation rates? And how have these common features evolved over time?

This paper investigates the evolution of these common features in national inflation rates. This is done by estimating the comovement in inflation rates via a dynamic factor model. We allow this comovement to change over time by incorporating time-varying coefficients and stochastic volatility into the dynamic factor model.

Our main result suggests an increase in comovement of inflation after the mid-1980s. In addition, we find that this increase in comovement coincided with the historical decline in the level and persistence of inflation for most G7 countries, Australia, New Zealand and Spain.

Chart 1: Inflation in 11 developed economies



We discuss a number of possible reasons that could be behind these two observations. As discussed extensively in a number of recent papers (see Bernanke (2004) for a survey), the fall in the level and persistence of inflation may have been a result of an improvement in monetary policy in each of the countries studied and/or due to 'good luck', ie a reduction in the volatility of non-policy shocks. Other possible reasons behind the fall in the level of inflation are listed in Rogoff (2003). These include improvement in fiscal policy, an increase in productivity and the effects of globalisation. The recent increase in comovement of inflation could also be explained by changes in the practice of monetary policy that are common across our sample of countries. As discussed in Section 4, the onset of globalisation could also be a reason behind this observation.

Our work is related to two important strands of the empirical literature. The first strand builds upon the methods developed by Stock and Watson (1998) and Forni, Hallin, Lippi and Reichlin (2001), and employs *fixed coefficient* factor models to study the international comovements of macroeconomic variables (see Kose, Otrok and Whiteman (2003) for real activity, and Ciccarelli and Mojon (2005) for inflation). The second strand uses small-scale VAR models to show that time-varying coefficients and stochastic volatility are important features of inflation dynamics in a number of industrialised countries (see Cogley and Sargent (2005) and Canova and Gambetti (2005)).

Our work links the literatures on fixed coefficient factor models and time-varying VARs by introducing time variation in a panel of 164 inflation indicators for the G7, Australia, New Zealand and Spain. In so doing, we characterise the temporal evolution of common features of inflation. Note that our empirical model is closely related to the time-varying dynamic factor model for GDP growth introduced by Del Negro and Otrok (2005).

The paper is organised as follows. Section 2 presents the empirical model and the international panel of data. Section 3 describes the evolution of the comovement in the level and persistence of inflation. Finally, Section 4 provides a discussion of possible reasons behind the observed changes in comovement. Appendix A provides details on the estimation technique and Appendix B provides details on the data.

2 A dynamic factor model for inflation in industrialised countries

This section describes the empirical model and the estimation procedure. The aim of our empirical model is to capture international *comovement* in inflation and to investigate how this has evolved over time. The main idea behind the empirical specification is that international comovements in inflation can be estimated using a dynamic factor model that distinguishes this comovement from idiosyncratic (country-specific) changes in national inflation. A number of recent contributions including Cogley and Sargent (2005) and Canova and Gambetti (2005) have suggested that the inflation process may have significantly changed over time. Our model allows for this possibility by incorporating time-varying coefficients and stochastic volatility in the dynamic factor framework.

2.1 *The empirical model*

Consider an international panel of inflation series $\pi_{i,t}$ where the subscript 'i' indexes the cross-section while 't' denotes the time dimension. The cross-section $i = 1...N$ ranges across different inflation series (eg inflation derived from different price indices) for each country in the sample.

Each inflation series, $\pi_{i,t}$, is described by the following dynamic factor model:

$$\pi_{i,t} = \beta_i^c F_t^c + \beta_i^w F_t^w + \varepsilon_{i,t} \tag{1}$$

where F_t^c denotes an 'idiosyncratic factor' or 'idiosyncratic component', while F_t^w is a 'common factor' or 'common component' with the associated factor loadings denoted by β_i^c and β_i^w. $\varepsilon_{i,t}$ is an error term. Note that in the description below we use the term 'factor' and 'component' interchangeably to refer to F_t^c and F_t^w. These should be interpreted as *statistical* objects.

The 'idiosyncratic factor' F_t^c describes the movement of inflation within each country in our sample. The 'common factor' F_t^w describes the *comovement* in inflation across countries. In Section 2.2, we describe the structure of the factor loadings that allows us to interpret F_t^c and F_t^w in this way.

The two components F_t^c and F_t^w are assumed to follow autoregressive processes of order P:

$$F_t^j = \alpha_t^j + \sum_{k=1}^{P} \rho_{k,t}^j F_{t-k}^j + v_t^j \tag{2}$$

where $j = \{c, w\}$. The coefficients in the AR model, $\Phi_t^j = \left[\alpha_t^j, \rho_{k,t}^j\right]$, are time varying and evolve as random walks

$$\Phi_t^j = \Phi_{t-1}^j + \eta_t^j \tag{3}$$

In addition, we assume that $E\left(v_t^j\right)^2 = \Sigma_t^j$ evolve as geometric random walks

$$\ln\left(\Sigma_t^j\right) = \ln\left(\Sigma_{t-1}^j\right) + \mu_t^j \tag{4}$$

We allow for serial correlation and heteroscedasticity in the error term and model the dynamics of $\varepsilon_{i,t}$ via the following time-varying AR(1) model:

$$\varepsilon_{i,t} = \rho_{i,t}\varepsilon_{i,t-1} + r_{i,t} \tag{5}$$

where

$$\begin{aligned} \rho_{i,t} &= \rho_{i,t-1} + u_{i,t} \\ \ln(R_{i,t}) &= \ln(R_{i,t-1}) + \varsigma_{i,t} \end{aligned}$$

with $R_{i,t} = E\left(r_{i,t}\right)^2$.

Finally, the vector $[\pi_{i,t}, \varsigma_t, \eta_t^j, \mu_t^j]'$ is distributed as

$$\begin{bmatrix} u_{i,t} \\ \varsigma_{i,t} \\ \eta_t^j \\ \mu_t^j \end{bmatrix} \sim N(0, V), \text{ with } V = \begin{bmatrix} q & 0 & 0 & 0 \\ 0 & g & 0 & 0 \\ 0 & 0 & Q & 0 \\ 0 & 0 & 0 & G \end{bmatrix} \quad \textbf{(6)}$$

2.2 Identification of F_t^w

For notational convenience, we rewrite equation **(1)** as:

$$\pi_{i,t} = \beta F_t + \varepsilon_{i,t} \quad \textbf{(7)}$$

where $F_t = [F_t^c; F_t^w]$. The comovement in inflation series as measured by the 'common factor' F_t^w is identified by the structure of the factor loading matrix. We label 'common factor' (or common component ie F_t^w) the unobserved component that is loaded by all inflation series in the panel. We label 'idiosyncratic factor' (or country-specific component ie F_t^c) the unobserved components that are exclusively loaded by the inflation series of each individual country. This implies the following structure for the matrix of factor loadings.

$$\beta = \begin{pmatrix} \beta_1^{country1} & 0 & 0 & 0 & \beta_1^{common} \\ . & 0 & 0 & 0 & . \\ \beta_{g1}^{country1} & 0 & 0 & 0 & \beta_{g1}^{common} \\ 0 & \beta_1^{country2} & 0 & 0 & \beta_{g1+1}^{common} \\ 0 & . & 0 & 0 & . \\ 0 & \beta_{g2}^{country2} & 0 & 0 & . \\ 0 & 0 & \beta_i^{countryJ} & 0 & . \\ 0 & 0 & 0 & \beta_1^{countryN} & . \\ 0 & 0 & 0 & . & . \\ 0 & 0 & 0 & \beta_{gN}^{countryN} & \beta_{g1+..+gN}^{common} \end{pmatrix}$$

The last column of this matrix identifies F_t^w, our measure of comovement of inflation across countries.

This model is subject to the rotational indeterminacy problem. For any $k \times k$ orthogonal matrix P, there is an equivalent specification such that the rotations $F_t^* = PF_t$ and $\beta^* = \beta P'$ produce the same distribution for $\pi_{i,t}$ as in the original factor model **(7)**. The implication is that the sign of the factor loadings and the sign of the factors are not separately identified. Following Geweke and Zhou (1996) and Bernanke, Boivin, Eliasz (2005), we impose further restrictions on the factor loadings. In particular, for each country we require the first $k \times k$ block of the factor loadings to be an identity matrix, where k denotes the number of factors per country. In our model $k = 2$.

2.3 Sources of time variation

The autoregressive process of F_t^c and F_t^w are modelled as time-varying. The factor loadings, in contrast, are fixed. Allowing simultaneously for time variation in the factor autoregressive coefficients, the factor variances, the factor loadings and the variance of the idiosyncratic component would greatly inflate the number of parameters in the model and hence would substantially increase the computational burden. A feasible alternative to the specification used in this paper is a fixed model for the factors but time-varying factor loadings (see Del Negro and Otrok (2005)).

In the current application, we do not consider such an alternative model for two reasons. First, a fixed coefficient factor model implies time-invariant inflation dynamics for each country in the panel. Recent empirical evidence, however, questions this assumption (see, for instance, Cogley and Sargent (2005) and Canova and Gambetti (2005)). Second, even with a time-invariant AR process for the factors, the model with time-varying factor loadings involves substantially more computation, with N passes through the Kalman filter and smoother at each iteration of the Gibbs sampler.

2.4 Estimation

The model in equations **(1)** to **(6)** is estimated using the Bayesian methods described by Kim and Nelson (2000). In particular, we employ a Gibbs sampling algorithm that approximates the posterior distribution. A detailed description of the prior distributions and the sampling method is given in Appendix A. Here, we summarise the basic algorithm in four steps:

1. Conditional on a draw for the F_t^c, F_t^w, we simulate the AR parameters and hyperparameters.

   - The AR coefficients Φ_t^j are simulated by using the methods described in Carter and Kohn (1994). Note that we only retain draws with roots inside the unit circle.
   - The volatilities of the shocks, Σ_t^j, are drawn using the date by date blocking scheme introduced by Jacquier, Polson and Rossi (2004).
   - The hyperparameters Q are drawn from an inverse Wishart distribution while the elements of G are simulated from an inverse gamma distribution.

2. Conditional on a draw of F_t^c, F_t^w, we draw the factor loadings (β) and the covariance matrix R.

- Given data on F_t^j and $\pi_{i,t}$, standard results for regression models can be used, and the coefficients and the variances are simulated from a normal and inverse gamma distribution.

3. Simulate F_t^c and F_t^w conditional on all the other parameters.

   - This step is carried out in a straightforward way by employing the procedures described by Bernanke, Boivin and Eliasz (2005), and Kim and Nelson (2000).

4. Go to step 1.

We use 34,000 Gibbs sampling replications and discard the first 30,000 as burn-in. We assess convergence by examining the variation of the posterior moments across the retained draws. In particular, we compare the posterior estimates calculated over subsets of the 4,000 draws. The results from this exercise, available upon request, show that the estimates are virtually identical across the subsets indicating convergence to the ergodic distribution.

2.5 Data

The panel includes 164 quarterly series of prices for 11 countries: United Kingdom, United States, Spain, New Zealand, Netherlands, Japan, Italy, Germany, France, Canada and Australia. The full sample is 1961:1-2004:3 and we use the first twelve years of data to calibrate the priors. Data are seasonally adjusted and standardised. CPI inflation, which is available for all countries, is the variable that we choose to explain. Appendix B provides a detailed description of the series.[1]

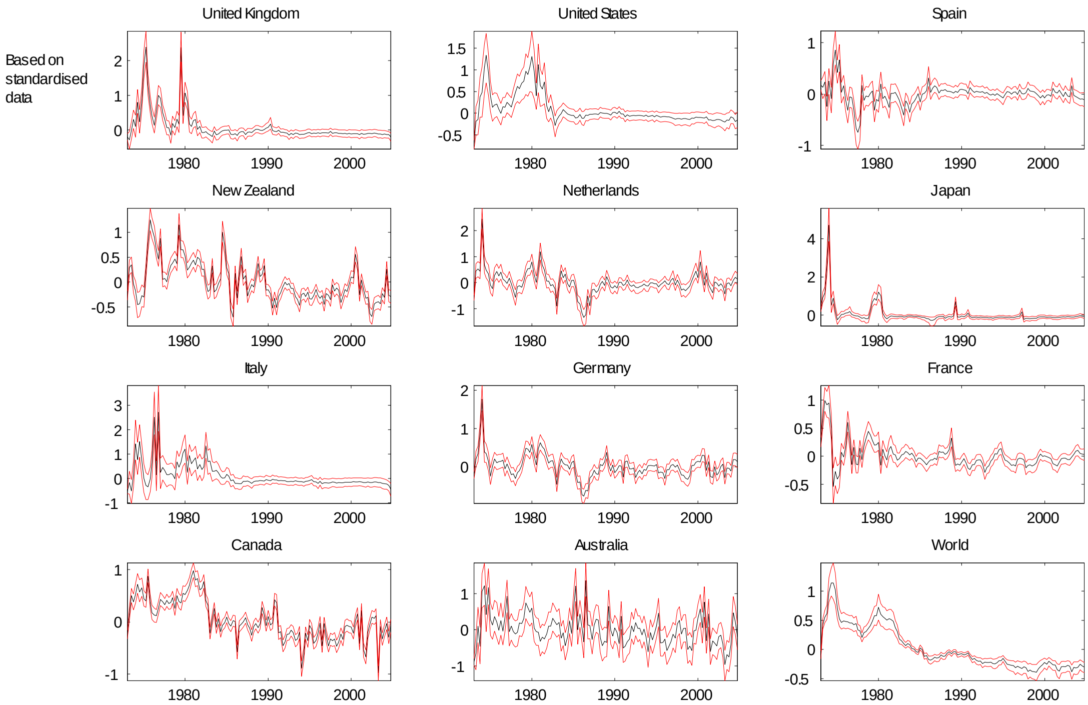
3 Results

3.1 Indicators of idiosyncratic and common movements in CPI inflation

We describe the movement of CPI inflation in each country and the international comovement in inflation by constructing 'indicators' of idiosyncratic and common movements. These can be constructed using equation **(1)**. In particular, the quantity $\beta_{cpi}^c F_t^c$ (where the subscript 'cpi' indicates the factor loading for CPI) can be interpreted as the movement in CPI inflation associated with the idiosyncratic component and provides information about national movements in inflation. We call this quantity the idiosyncratic indicator. The quantity $\beta_{cpi}^w F_t^w$ can be

[1]Our panel of inflation series is unbalanced. A factor model estimated on a balanced version of this panel produces qualitatively similar results. However these estimates were less precise due to the use of fewer data points. In order to maximise the information used in our analysis we retain the larger unbalanced data set.

Chart 2: Indicators of idiosyncratic and common movement



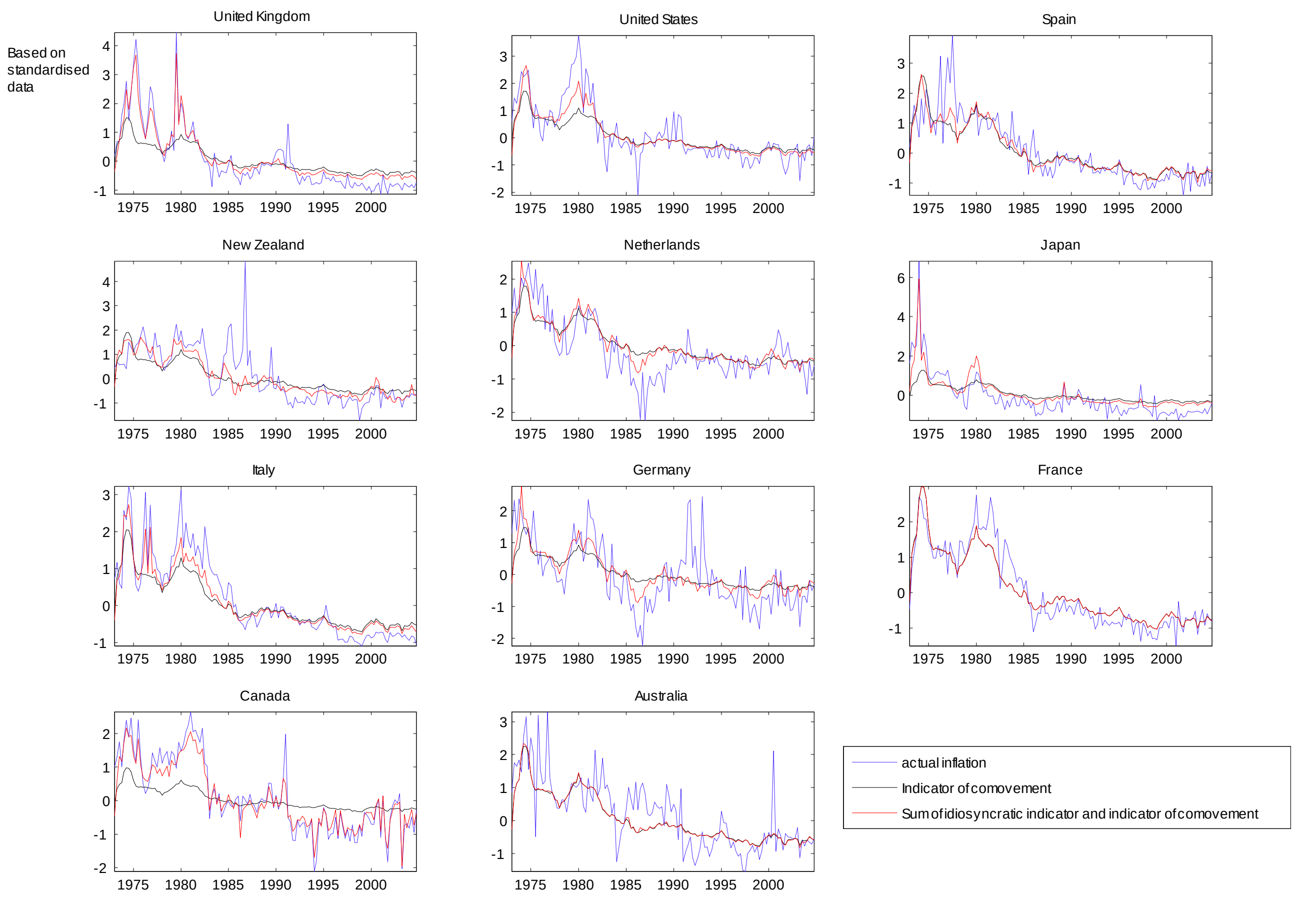
interpreted as the comovement in CPI inflation across countries. We call this quantity the indicator of comovement in CPI inflation. We compute eight country indicators, which are reported in Chart 2, and eight indicators of common comovement, which are available upon request. The bottom-right chart of Chart 2 summarises the information in the indicators of common comovement by plotting, at each point in time, the average value of these indicators across all countries. The dark lines are median values and red lines represent the central 68th posterior bands. Note also that as the underlying data is standardised, the units in Chart 2 represent information about CPI inflation relative to its mean. The bottom-right panel of Chart 2 plots the indicator of common movement in CPI inflation. As mentioned above, movements in this indicator capture changes in CPI inflation that are common across countries. This indicator is statistically significant over the full sample. It is positive before 1985 and negative after suggesting that after 1985 there is a common fall in CPI inflation in our sample. The first peak in this indicator coincides with the oil price increase in 1974 and appears to be statistically and economically more important than the second peak at the end of 1979. The correlation between the oil price change and the indicator one year later is 0.43. Excluding the oil price shock in 1973 and the subsequent inflation rise in 1974, however, reduces the correlation to only 0.04.[2] This implies that this indicator captures common features beyond the oil price.[3]

[2]The measure of oil price is the IMF synthetic Brent crude oil series.

[3]A similar result for output can be found in Kose, Otrok and Whiteman (2003).

Turning to the country-specific indicators, we identify differences and similarities across nations. These indicators were more volatile during the 1970s and the beginning of the 1980s and are statistically different from zero in a few historical periods which are typically concentrated at the beginning of the sample. Canada, Australia and France are exceptions. For Canada the country-specific indicator was important over most of the sample with the exception of the second half of the 1980s. In contrast, for Australia and France the country indicator has fluctuated around zero.

Chart 3: Actual inflation and indicators



These indicators can also be used to evaluate how international comovement in CPI inflation has changed over time. Following Canova, Ciccarelli and Ortega (2005), for each country we plot the median values of the indicator of comovement, $\beta^{w}_{cpi}F^{w}_{t}$, (in dark) together with the sum of this indicator and country-specific indicators, $\beta^{c}_{cpi}F^{c}_{t} + \beta^{w}_{cpi}F^{w}_{t}$, (in dotted red), and actual inflation (in blue). Sizable differences between the dark and red lines identify periods in which comovement in inflation rates is small.

Idiosyncratic indicators are closely related to national inflation during the second half of the 1970s and the first years of the 1980s, consistent with the conventional wisdom that national incomes policies were insufficient to achieve durable control of inflation in the United Kingdom, Spain, Italy, Germany and New Zealand.

Except for Canada and Japan, the inflation peaks in 1974 are typically associated with small gaps between dark and red lines, possibly suggesting that a common worldwide event, such as the first oil price shock, was associated with the rise in inflation. The second peak in US inflation is clearly country specific; similarly, the pickup in UK inflation at the beginning of the 1990s is shared by no other country. Canada and the Netherlands on the one hand, and Australia and France on the other hand represent two extremes: in the former, the indicator of comovement is unimportant; in the latter, this indicator plays a significant part.

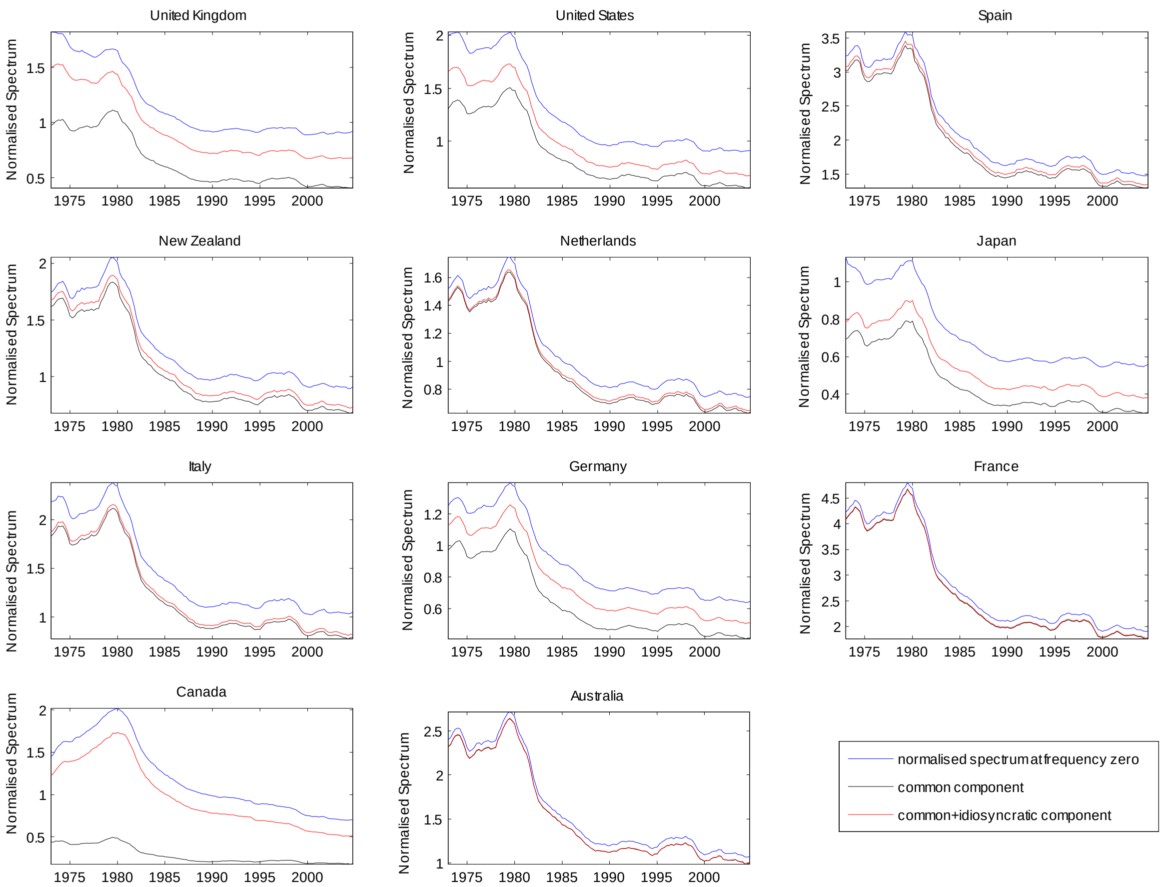
During the past two decades the difference between $\beta^{w}_{cpi} F^{w}_{t}$ (dark line) and $\beta^{c}_{cpi} F^{c}_{t} + \beta^{w}_{cpi} F^{w}_{t}$ (red line) virtually disappear in most countries. This suggests that comovement in CPI inflation between countries has been higher over this period.

3.2 Inflation persistence

A number of authors including Cogley and Sargent (2002) and Canova, Gambetti and Pappa (2006) have argued that since the beginning of the 1980s inflation persistence has remarkably declined in several industrialised economies. Our model allows us to investigate whether this change in inflation persistence was common across our sample of countries. This is done, as in the previous section, via the observation equation **(1)**. In particular, we define the persistence of the comovement in CPI inflation as the normalised spectral density of the common component F^{w}_{t} multiplied by the square of the corresponding loading (β^{w}_{cpi}). Similarly, we construct idiosyncratic measures of CPI inflation persistence by computing the normalised spectra of F^{c}_{t} multiplied by the square of the corresponding factor loadings. Chart 4 displays the persistence of actual CPI inflation (blue line), persistence of the comovement in CPI inflation (black line) and the sum of common and idiosyncratic measures of inflation persistence (red line). As in Chart 3, gaps between the black and the red lines would indicate that comovement in inflation persistence was not important.

The main results can be summarised as follows. The decline in the persistence of national inflation rates, which earlier contributions have only documented for single countries, appears to be a more widespread phenomenon with a common decline in persistence. This is shown by the relatively small difference between the red and the black lines which is evident for most countries (with the exception of Canada).

Chart 4: Inflation persistence: common and idiosyncratic components

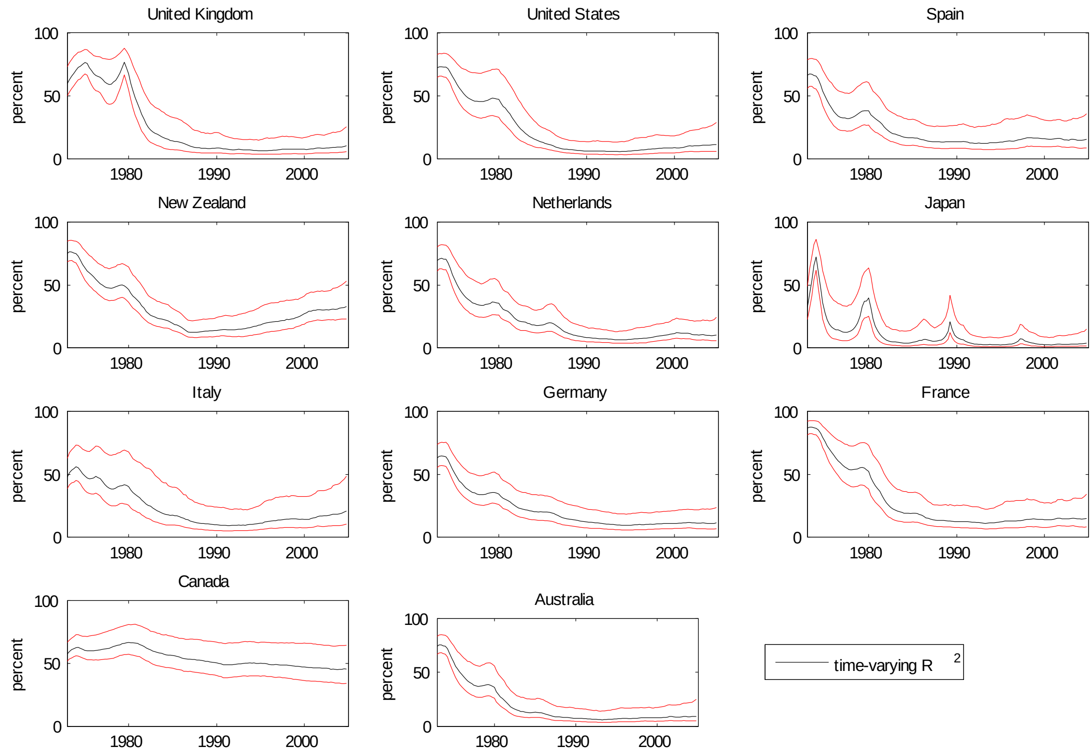


3.2.1 *Time-varying R^2*

A number of recent studies have documented a fall in the ability of shocks inherited from the past to explain current and future variability of US inflation. These studies include Cogley and Sargent (2006), D'Agostino and Giannone and Surico (2006). As D'Agostino, Giannone and Surico (2006) point out, one reason behind this decline may be an improvement in the conduct of monetary policy – ie a central bank that places a high weight on maintaining low inflation acts quickly to offset inflationary shocks and therefore reduces the impact of these shocks on current and future inflation outcomes. Cogley and Sargent (2006) argue that the decline in the contribution of past shocks to current inflation is closely linked to the decline in inflation persistence.

Our dynamic factor model allows us to extend the analysis in these papers to a larger set of

Chart 5: Evolving R-Squared



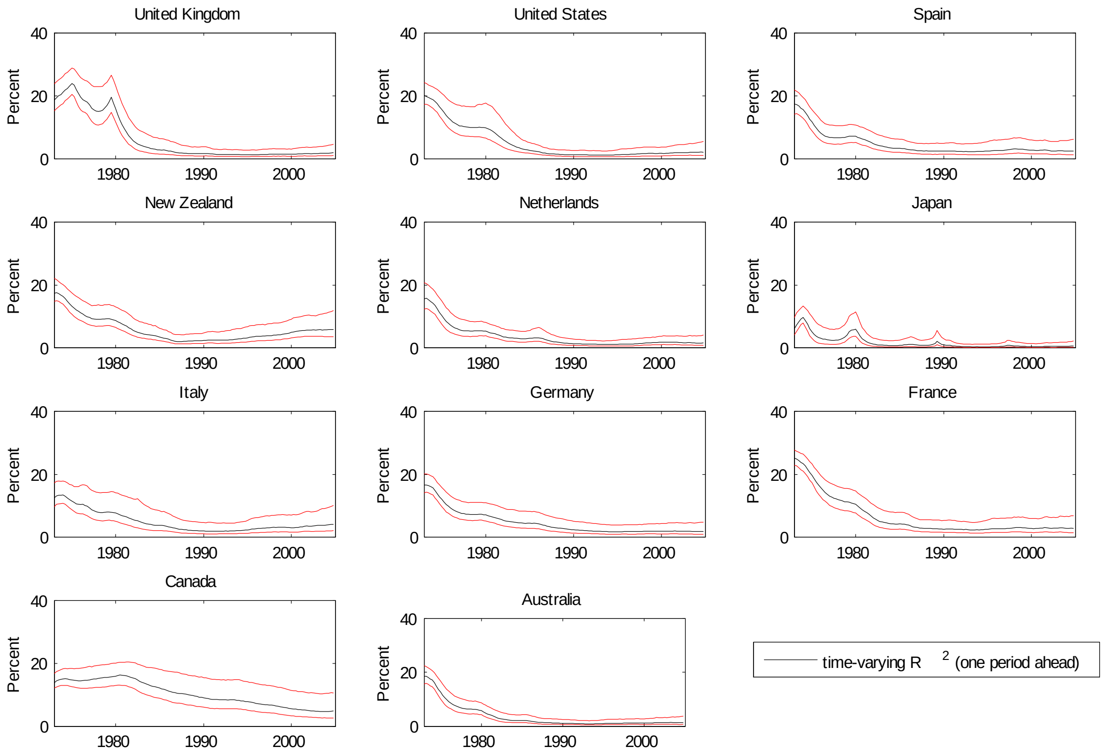
countries. In order to assess the contribution of past shocks we compute a statistic (at each point in time) that is analogous to the R^2 statistic in linear regression models. As shown in Cogley and Sargent (2006), this time-varying R^2 is given as the ratio of the fraction of variation in CPI inflation due to past shocks and its total variation.[4] In Chart 5 we plot this time-varying version of the R^2 statistic for CPI inflation for each country in our sample. Note that values of this statistic closer to 100% suggest a high degree of (in-sample) contribution of past shocks.

The second panel in the top row corroborates the evidence of declining importance of past shocks for the United States. The novel finding is that the fall is shared by all countries except Canada. The importance of past shocks has been steadily declining during the 1980s, and today it is far smaller than it was during the 1970s.

In Chart 6, we report for each country the time-varying R^2 statistics associated with the one year forecast horizon. This statistic measures the role of past shocks in explaining one year ahead CPI

[4]This is computed as the ratio of the conditional variance of inflation to the unconditional variance. The unconditional variance is the integrated spectrum of inflation based on our estimated model. The conditional variance is the difference between the unconditional variance and the variance of the idiosyncratic component.

Chart 6: Evolving R-Squared- one year forecast horizon



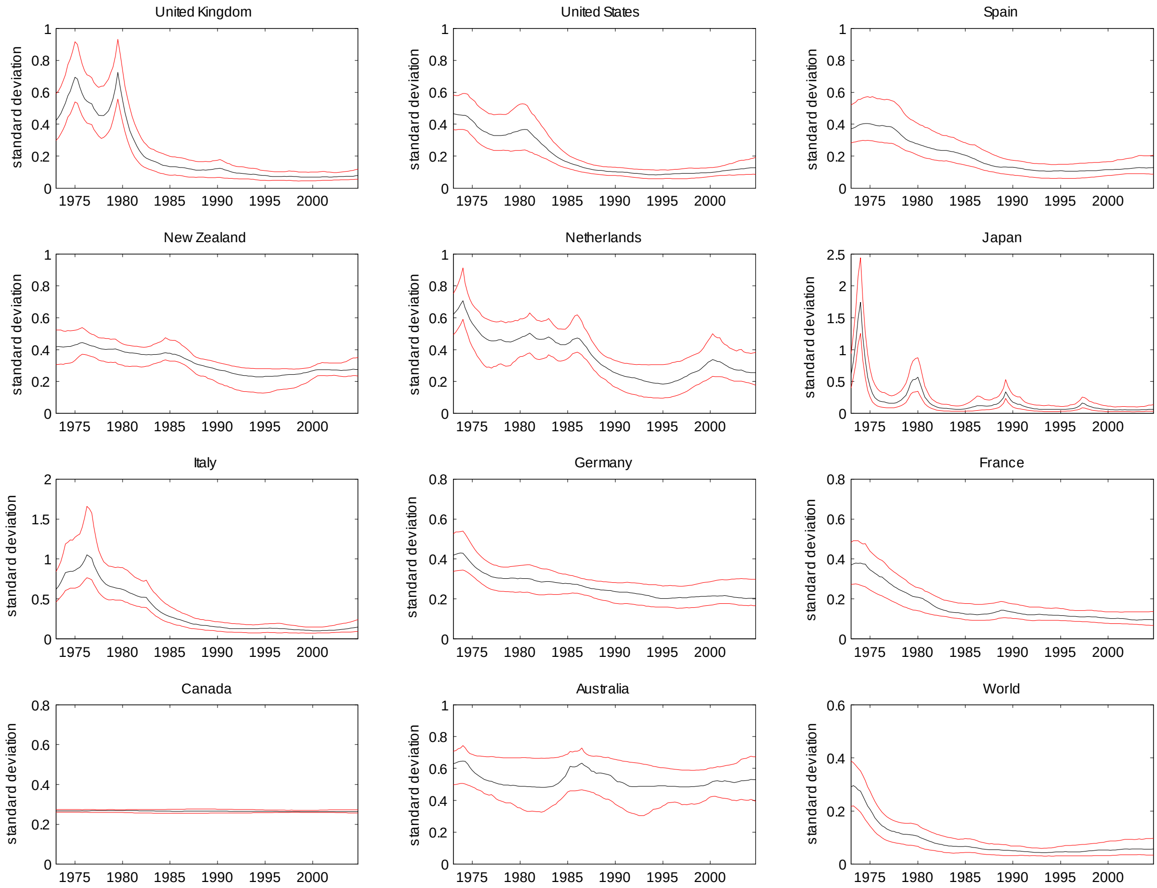
inflation variability. Chart 6 indicates that the fall in the contribution of past shocks is also apparent out-of-sample.

3.3 Stochastic volatility

Chart 7 plots the stochastic volatility of the two factors in equation **(1)**. Volatilities of the idiosyncratic components are far larger than the volatility of the common component, especially during the 1970s and the beginning of the 1980s. The decline is particularly pronounced for the United Kingdom, United States and Japan. The dynamics for Germany and Australia are fairly stable. The stochastic volatility of the common component, in contrast, is characterised by small magnitudes and little time variation.

It is worth noting that while the reductions in volatility are broadly concentrated around the middle of the sample, they are not synchronised across nations, suggesting that the source of change is truly country specific. Domestic shocks, differences in the transmission mechanism of a common shock as implied, for instance, by differences in nominal and/or real rigidities, and national economic policies are consistent with the different timings in the decline of volatility. A common international shock that affects national economies at the same time, in contrast, is inconsistent with events.

Chart 7: Standard deviation of factor innovations



4 Discussion of the empirical results

The estimates presented above point to a number of results. First, they provide strong evidence in favour of a fall in the level, volatility and persistence of inflation across industrialised countries, confirming the evidence on the 'great moderation' contained in Cogley and Sargent (2005) Canova and Gambetti (2005) and Primiceri (2005). Second, they suggest that the fall in the level and persistence of inflation was common across the countries in our sample and this comovement increased in the last decades of the sample. In this section, we discuss possible explanations for these results.

The onset of the ‘great moderation’ and the fall in the level of inflation across the industrialised world has been discussed extensively in the recent literature. One explanation for this phenomenon, advanced by papers such as Clarida, Galí and Gertler (1998) and Nelson (2000) is that the practice of monetary policy has improved. These authors argue that in the recent past, monetary policy has reacted more actively to counter inflationary pressure and this change in policy has led to a more benign outcome for inflation. The view that improved monetary policy was the driving force behind movements in inflation has not gone unchallenged. A number of empirical contributions, including Canova and Gambetti (2005), Primiceri (2005) and Sims and Zha (2006) argue that the most recent experience of low and stable inflation can be explained by a favourable macroeconomic environment, in the form of small adverse shocks across the countries in our panel.[5]

Rogoff (2003) discusses a number of additional (candidate) reasons behind the fall in inflation across the industrialised world. Tighter fiscal policy seen in industrialised countries in the 1990s, may have played a part in bringing about lower inflation. Similarly, an increase in productivity growth may have helped the disinflation process by reducing the incentives for a central bank to inflate. However, Rogoff (2003) notes that this explanation does not fit the recent experience of European countries where both inflation and the level of productivity has declined. Rogoff (2003) discusses two channels through which globalisation may have an impact on national inflation rates. First, increased competition in the good markets (resulting from globalisation) reduces the wedge between the monopoly level of output and the benchmark competitive level and, in turn, it reduces private sector’s inflation expectations. Second, increased competition leads to greater price flexibility, and therefore it reduces the impact of monetary policy on real activity. Bean (2006) suggests that the impact of globalisation on inflation may come about by flattening the short-run trade-off between inflation and the output gap. This occurs, for example, as increased competition from economies with a large supply of labour reduces the cyclical sensitivity of profit margins. Similarly, if it becomes increasingly easier to off-shore activities to economies with low wages, domestic workers have less of an incentive to push for higher wages when unemployment falls and employers are in a better position to resist such claims.

This discussion also points to possible reasons behind international comovement in inflation. For example, if similar monetary policy is adopted across countries then we might expect inflation to move in a similar manner. Clarida, Galí and Gertler (1998) argue that the central banks of Japan, Germany and the US have pursued an implicit form of inflation targeting since the beginning of the 1980s. During the 1990s, inflation targeting has been explicitly adopted in a number of countries, including the UK, New Zealand, Sweden, Canada and Australia. The evolution in the intellectual climate and policy framework is consistent with the close movements of national inflation rates observed over the recent past. Similarly, the onset of globalisation (which affects the economies in our sample) may lead to an increase in the comovement of inflation.

[5]It should be noted that the ability of structural VARs to effectively capture changes in the policy reaction function has been questioned by commentators. See Bernanke (2004).

5 Conclusions

Inflation rates today are more similar across countries than in the 1970s. We use a dynamic factor model with time-varying coefficients and stochastic volatility to identify common features in a panel of 164 series for the most industrialised economies in the world.

Our results suggest that there has been a fall in the level, persistence and volatility of inflation across our sample of countries. The fall in the level and persistence of inflation has coincided in the past two decades with a substantial increase in international comovement in inflation rates.

We discuss a number of candidate explanations for these results. An improvement in monetary policy across our sample of countries could explain the change in inflation dynamics. The increase in comovement in inflation is consistent with this change having occurred in most countries in our panel. The onset of globalisation provides another explanation for the change in inflation dynamics and the increase in comovement.

Appendix A: Priors and estimation

Consider the time-varying factor model in **(1)** and **(2)**.

Prior distributions and starting values

Factors and factor loadings

Following Bernanke, Boivin and Eliasz (2005), we centre our prior on the factors (and obtain starting values) by using a Principal Component (PC) estimator applied to the inflation series for each country. The covariance of the states ($P_{0/0}$) is set equal $I_{0.01}$ where I_n denotes an identity matrix with n on the main diagonal.

Starting values for the factor loadings are also obtained from the PC estimator. The prior on the diagonal elements of R is assumed to be inverse gamma:

$$R_{ii} \sim IG(3, 0.001)$$

In choosing a diffuse prior, we closely follow Bernanke, Boivin and Eliasz (2005).

AR coefficients

Following Del Negro and Otrok (2005) we treat the initial conditions for the AR coefficients Φ_0 as an additional parameter and add a step in the Gibbs sampling procedure to estimate them.

Elements of Σ_t

The prior for the diagonal elements of the VAR covariance matrix (see equation **(4)**) is as follows:

$$\ln h_0 \sim N(\ln \mu_0, I)$$

where μ_0 is set equal to 0.1.

Hyperparameters

The prior on Q is assumed to be inverse Wishart

$$Q_0 \sim IW\left(\bar{Q}_0, T_0\right)$$

where $\bar{Q}_0$ is assumed to be $I_{1\times 10^{-3}}$ and T_0 is the length of the sample used to obtain starting values for the algorithm.

In line with Cogley and Sargent (2002), we postulate an inverse-Gamma distribution for the elements of G,

$$\sigma_i^2 \sim IG\left(\frac{10^{-4}}{2}, \frac{1}{2}\right)$$

Simulating the posterior distributions

Factors and factor loadings

This closely follows Bernanke, Boivin and Eliasz (2005). Details can also be found in Kim and Nelson (2000).

Factors

The distribution of the factors F_t is linear and Gaussian:

$$\begin{array}{l} F_T \backslash X_{i,t}, R_t, \Xi \sim N\left(F_{T\backslash T}, P_{T\backslash T}\right) \\ F_t \backslash F_{t+1}, X_{i,t}, R_t, \Xi \sim N\left(F_{t\backslash t+1,F_{t+1}}, P_{t\backslash t+1,F_{t+1}}\right) \end{array}$$

where $t = T - 1, ..1,$ Ξ denotes a vector that holds all the other parameters and:

$$\begin{aligned} F_{T\backslash T} &= E\left(F_T \backslash X_{i,t}, R_t, \Xi\right) \\ P_{T\backslash T} &= Cov\left(F_T \backslash X_{i,t}, R_t, \Xi\right) \\ F_{t\backslash t+1,F_{t+1}} &= E\left(F_t \backslash X_{i,t}, R_t, \Xi, F_{t+1}\right) \\ P_{t\backslash t+1,F_{t+1}} &= Cov\left(F_t \backslash X_{i,t}, R_t, \Xi, F_{t+1}\right) \end{aligned}$$

As shown by Carter and Kohn (1994), the simulation proceeds as follows. First we use the Kalman filter to draw $F_{T\backslash T}$ and $P_{T\backslash T}$ and then proceed backwards in time using:

$$F_{t|t+1} = F_{t|t} + P_{t|t} P_{t+1|t}^{-1} \left(F_{t+1} - F_t\right)$$

$$P_{t|t+1} = P_{t|t} - P_{t|t} P_{t+1|t}^{-1} P_{t|t}$$

If more than one lag of the factors appears in the transition equation, this procedure has to be modified to take account of the fact that the covariance matrix of the shocks to the transition equation (used in the filtering procedure described above) is singular. For details see Kim and Nelson (2000).

Elements of R

As in Bernanke, Boivin and Eliasz (2005), R is a diagonal matrix. The diagonal elements R_{ii} are drawn from the following inverse gamma distribution:

$$R_{ii} \sim IG\left(\bar{R}_{ii}, T + 0.001\right)$$

where

$$\bar{R}_{ii} = 3 + \hat{e}_i' \hat{e}_i + \beta_i' \left[\bar{M}_0^{-1} + \left(F_{i,t}' F_{i,t}\right)^{-1}\right]^{-1} \beta_i$$

and $M_0 = I$.

Elements of β

The factor loadings are sampled from

$$\beta_i \sim N\left(\bar{\beta}_i, R_{ii} \bar{M}_i^{-1}\right)$$

where $\bar{\beta}_i = \bar{M}_i^{-1}\left(F_{i,t}' F_{i,t}\right)\hat{\beta}_i$, $\bar{M}_i = \bar{M}_0 + \left(F_{i,t}' F_{i,t}\right)$ and $\hat{\beta}_i$ represents an OLS estimate.

Time-varying AR

Given an estimate for the factors, the model becomes an AR model with drifting coefficients and covariances. This model has become fairly standard in the literature and details on the posterior distributions can be found in a number of papers including Cogley and Sargent (2005) and Primiceri (2005). Here, we describe the algorithm briefly.

AR coefficients Φ_t

As in the case of the unobserved factors, the time-varying AR coefficients are drawn using the methods described in Carter and Kohn (1994). Following Del Negro and Otrok (2005) we add an additional step in the sampler to estimate the initial condition Φ_0. Starting from a prior for $\Phi_0 \sim N(\bar{\Phi}_0, \bar{V}_0)$ obtained via OLS regressions on the pre-sample 1961Q1-1972Q4, we obtain the posterior estimate of Φ_0 by updating the mean and variance $\bar{\Phi}_0$ and $\bar{V}_0$ using the methods described in Carter and Kohn (1994).

Note that we require the roots of the AR process to be inside the unit circle for each t.

Elements of Σ_t

Following Cogley and Sargent (2005), the diagonal elements of the AR covariance matrix are sampled using the methods described in Jacquier, Polson and Rossi (2004).

Hyperparameters

Conditional on F_t, $\Phi_{j,t}$ and Σ_t, the innovations to $\Phi_{j,t}$ and Σ_t are observable, which allows us to draw the hyperparameters—the elements of Q and G—from their respective distributions.

Appendix B: Data

Description of variables

No.	Description	Country
1	CPI	UK
2	PPI / WPI	UK
3	RPI Total Food	UK
4	RPI Total Non-Food	UK
5	RPI Total All items other than seasonal Food	UK
6	GDP Deflator	UK
7	QMA Data	UK
8	Total Wages and Salaries	UK
9	METALS	UK
10	AGR. RAW MATERIALS	UK
11	BEVERAGES	UK
12	FOOD	UK
13	Petrolium Average Crude Pounds Per barrel	UK
14	CPI	US
15	US CAPITAL EQUIPMENT	US
16	US CPI - ALL ITEMS LESS FOOD	US
17	US CPI - ALL ITEMS LESS ENERGY	US
18	US CPI - ALL ITEMS LESS FOOD and ENERGY	US
19	US CPI - DURABLES	US
20	US CPI - NEW VEHICLES	US
21	US CPI - SERVICES	US
22	US EXPORT PRICES	US
23	US GDP DEFLATOR VOLN	US
24	US IMPLICIT PRICE DEFLATOR - GNP	US
25	US IMPORT PRICES	US
26	US PPI - COMMERCIAL ELECTRIC POWER	US
27	US PPI - COAL	US
28	US PPI - CRUDE FUEL	US
29	US PPI - ELECTRICAL MACHINERY and EQUIPMENT	US
30	US PPI - IRON and STEEL	US
31	SD CPI - FOOD	SW
32	SD CPI - HOUSING, FUEL and ELECTRICITY	SW
33	ES CPI	SP
34	ES EXPORT UNIT VALUE	SP
35	ES CPI - RENT	SP
36	ES IMPORT UNIT VALUE	SP
37	ES PPI	SP
38	ES PPI - MANUFACTURING ALL ITEMS	SP
39	ES PPI WPI	SP
40	NZ CPI	NZ
41	NZ CPI - ENERGY	NZ
42	NZ CPI - HOUSING	NZ
43	NZ CPI: FOOD (QUARTERLY)	NZ
44	NZ EXPORT PRICE - BUTTER	NZ
45	NZ EXPORT PRICE INDEX	NZ
46	NZ EXPORT PRICE INDEX: DAIRY PRODUCTS	NZ
47	NZ EXPORT PRICE INDEX: MEAT	NZ
48	NZ EXPORT PRICE INDEX: MEAT, WOOL and BY-PRODUCTS	NZ
49	NZ EXPORT PRICE INDEX: PASTORAL and DAIRY PRODUCTS	NZ
50	NZ INFLATION RATE	NZ
51	NZ MARKET PRICE - LAMB, NEW ZEALAND (LONDON)	NZ
52	NZ PPI	NZ
53	NZ PPI - MANUFACTURING	NZ
54	NZ PPI WPI	NZ
55	NL CPI	NL
56	NL CPI - ENERGY	NL
57	NL CPI - EXCLUDING FOOD and ENERGY	NL
58	NL CPI - FOOD	NL
59	NL CPI: RENT INCLUDING IMPUTED RENT	NL
60	NL PPI	NL
61	NL PPI - OUTPUT	NL
62	NL EXPORT UNIT VALUE	NL
63	NL IMPORT UNIT VALUE	NL
64	NL PPI WPI	NL
65	JP CPI	JP
66	JP CPI - ENERGY	JP
67	JP DOMESTIC CORP.GOODS PRICE INDEX-CHEMICALS and RELATED PRODS.	JP
68	JP DOMESTIC CORP.GOODS PRICE INDEX-ELECTRICITY, GASand WATER	JP
69	JP DOMESTIC CORP.GOODS PRICE INDEX-GENERAL MACHINERY and EQUIP.	JP
70	JP DOMESTIC CORP. GOODS PRICE INDEX - METAL PRODUCTS	JP
71	JP DOMESTIC CORP.GOODS PRICE INDEX-PULP,PAPER and RELATED PRDS.	JP
72	JP DOMESTIC CORP.GOODS PRICE INDEX-PETROLEUM and COALPRODS.	JP
73	JP IMPORT UNIT VALUE	JP
74	JP MONTHLY EARNINGS - MANUFACTURING	JP
75	JP PPI - IRON and STEEL	JP
76	JP PPI - CHEMICALS and CHEMICAL PRODS	JP
77	JP PPI - MANUFACTURING	JP
78	JP UNIT LABOUR COST - MANUFACTURING	JP
79	JP WAGE INDEX: CASH EARN. - MANUFACTURING (SEE JPWAMFROE)	JP
80	IT CPI	IT
81	IT CPI - ENERGY	IT
82	IT CPI - EXCLUDING FOOD and ENERGY	IT
83	IT CPI - FOOD	IT
84	IT CPI - HOUSING	IT
85	IT CPI - SERVICES LESS HOUSING	IT

Description of variables (continued)

No.	Description	Country
86	IT CPI EXCLUDING TOBACCO (FOI)	IT
87	IT CPI INCLUDING TOBACCO (NIC)	IT
88	IT HOURLY WAGE RATE : INDUSTRY	IT
89	BD CPI	GER
90	BD CPI - FOOD AND ALCOHOL-FREE DRINKS (EXCL. REST)	GER
91	BD EXPORT PRICES	GER
92	BD HOURLY EARNINGS: MANUFACTURING	GER
93	BD IMPORT UNIT VALUE	GER
94	BD PERSONAL SAVINGS RATIO (PAN BD Q0191)	GER
95	BD PPI	GER
96	BD WAGE and SALARY RATES: MONTHLY-OVERALL ECONOMY(PANBD M0191)	GER
97	BD WHOLESALE OUTPUT PRICE INDEX REBASED TO 1975=100	GER
98	BD WPI	GER
99	FR CPI	FR
100	FR CONSTRUCTION COST INDEX - RESIDENTIAL PROPERTY	FR
101	FR CPI - ENERGY	FR
102	FR CPI - EXCLUDING FOOD and ENERGY	FR
103	FR CPI - FOOD	FR
104	FR CPI - SERVICES EXCLUDING RENT	FR
105	FR EXPORTS (IN US$)	FR
106	FR HOURLY WAGE RATE: INDUSTRY	FR
107	FR HOURLY WAGE RATES ALL ACTIVITIES	FR
108	FR IMPORT PRICE - GRADE A SETTLEMENT LEATHER (LONDON)	FR
109	FR IMPORT PRICE - GRAIN (CHICAGO)-PRICE PER 60 POUND BUSHEL	FR
110	FR IMPORT PRICE - SETTLEMENT LEAD (LONDON)	FR
111	FR IMPORT PRICE - SETTLEMENT ZINC (LONDON)	FR
112	FR IMPORTS CIF (IN US$)	FR
113	FR PPI - AGRICULTURAL GOODS	FR
114	FR PPI - METAL PRODUCTS	FR
115	FR PPI - MANUFACTURED PRODUCTS	FR
116	FR PPI - INTERMEDIATE GOODS EXCLUDING ENERGY	FR
117	FR PPI- IMPORTED RAW MATERIALS	FR
118	FR WAGE RATE : HOURLY - MANUAL WORKERS	FR
119	FN CPI	FI
120	FN CPI - ENERGY	FI
121	FN CPI - EXCLUDING FOOD and ENERGY	FI
122	FN CPI - FOOD	FI
123	FN CPI - HOUSING	FI
124	FN EXPORT UNIT VALUE	FI
125	FN EXPORTS (IN US$)	FI
126	FN HOURLY EARNINGS - MANUFACTURING	FI
127	FN IMPORTS CIF (IN US$)	FI
128	FN PPI	FI
129	CN CPI	CN
130	CN CPI - EXCLUDING FOOD and ENERGY	CN
131	CN CPI - SERVICES EXCLUDING RENT	CN
132	CN CPI ENERGY	CN
133	CN CPI: ALCOHOLIC BEVERAGES and TOBACCO PRODUCTS	CN
134	CN CPI: ALL ITEMS EXCLUDING FOOD	CN
135	CN CPI: ALL ITEMS EXCLUDING FOOD and ENERGY	CN
136	CN CPI: DURABLE GOODS	CN
137	CN CPI: FOOD	CN
138	CN CPI: GASOLINE	CN
139	CN CPI: GOODS	CN
140	CN CPI: HOUSING	CN
141	CN CPI: NONDURABLE GOODS	CN
142	CN EXPORTS (IN US$)	CN
143	CN GDP (IMPLICIT PRICE DEFLATOR)	CN
144	CN HOURLY EARNINGS - MANUFACTURING	CN
145	CN IMPORTS CIF (IN US$)	CN
146	CN INDUSTRIAL PRICE INDEX: ALL COMMODITIES	CN
147	CN INDUSTRIAL PRICE INDEX:BLEACHED SULPHATE WOODPULP	CN
148	CN INDUSTRIAL PRICE INDEX:LINER BOARD	CN
149	CN INDUSTRIAL PRICE INDEX:LUMBER and TIES, SOFTWOOD	CN
150	CN INDUSTRIAL PRICE INDEX:NEWSPRINT PAPER	CN
151	CN MARKET PRICE - ALUMINUM, CANADA (UK)	CN
152	CN MARKET PRICE - NICKEL, LONDON METALS EXCHANGE, SPOT, CIF	CN
153	CN MARKET PRICE-POTASH,FOB CANADA(VANCOUVER)(AVG OF DAILIES)	CN
154	CN PPI	CN
155	AU CPI	AUS
156	AU EXPORT PRICES	AUS
157	AU GDP DEFLATOR VOLN	AUS
158	AU GFCF:PRIVATE - DWELLINGS (IPD)	AUS
159	AU GDP (IMPLICIT PRICE DEFLATOR)	AUS
160	AU IMPORT PRICES	AUS
161	AU MARKET PRICE - BEEF, ALL ORIGINS (US PORTS)	AUS
162	AU GFCF:PRIVATE - MACHINERY (IPD)	AUS
163	AU GFCF:PUBLIC (IPD)	AUS
164	AU PPI	AUS

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