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Abstract

Recent research has found evidence of increasing comovement in CPI inflation rates across industrialised countries. This paper considers whether this can be attributed to greater global integration of product markets. To examine this question, we build a data set of 28 matched product category price indices for fourteen advanced economies for 1998 Q1 to 2008 Q2, and decompose the inflation rates into a world factor, country-specific factors, and category-specific factors using a Bayesian dynamic factor model with Gibbs sampling. We find that the category-specific factors account for a large part of the comovement in the prices of goods which are intensive in internationally traded primary commodities; but this is less evident for other traded goods. We also find that both the world factor and the category-specific factors become more significant in explaining the movement in the relative prices in the second half of our sample.

Key words: Disaggregated international price, dynamic factor model, Gibbs sampling.

JEL classification: E30, E52.

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Summary

Recent research has found that a common component explains a greater proportion of quarterly inflation movements in industrialised countries after the mid-1980s relative to the period before that. There are two possible explanations for this finding. First, the increased comovement in inflation rates could reflect adoption of similar monetary policy across the industrialised countries. For example, it has been argued that the central banks of Japan, Germany and the United States have pursued an implicit form of inflation targeting since the beginning of the 1980s; and during the 1990s, inflation targeting has been explicitly adopted in a number of industrialised countries. Second, it could reflect the increased integration of global product and factor markets, which subjects the relative prices of similar products in different countries to common demand and cost shocks. Although the overall inflation rate in an economy is ultimately determined by domestic monetary policy, fluctuations in relative prices can affect headline inflation rates in the short run.

This paper examines the extent to which the increased comovement in inflation rates across countries can be attributed to greater global integration of product markets by using a statistical approach to decompose fluctuations in quarterly inflation rates into a world factor, country-specific factors, and category-specific factors. The world factor captures the common pattern in inflation rates across all product categories across all countries. Country-specific factors capture the common pattern in inflation rates across all product categories within the same country. Finally, the category-specific factors capture the common pattern in inflation rates across countries for the same product categories (eg clothing).

The point of this exercise is that the international common component found in previous research may not necessarily be the one that affects every single sector or products in different economies. It may also be product specific. For example, the international factors affecting rice prices across countries may be different from international factors affecting car prices. Therefore, analysis that ignore these good-specific factors may underestimate the true nature and the size of the contribution of international factors in explaining cross-country comovements in national inflation rates. Our approach allows us to explore this issue further. If it is indeed the adoption of similar monetary policy rather than global integration of product markets that is driving the

international comovement in inflation rates, then we should not find any evidence for comovement in product category inflation rates. By contrast, if the international comovement in inflation rates is driven by integration of global markets, which subjects prices of similar products to global cost and demand shocks, we would expect to see cross-country comovement in product category inflation rates.

We find that product category factors explain a significant proportion of fluctuations in quarterly inflation rates for products that are intensive in primary commodities; but this is less evident for other traded goods. We also find that both the world factor and product category factors have become more significant in explaining the fluctuations in quarterly inflation rates for most product categories. Finally, the sharp pickup in inflation rates during 2007-08 was captured by our estimated world factor, but in some countries the rise in the inflation rate also reflected country-specific factors.

1 Introduction

This paper examines the extent to which the increased comovement in headline inflation rates across countries found in Ciccarelli and Mojon (2005) and Mumtaz and Surico (2006) can be attributed to greater global integration of product markets. In a study of OECD countries, Ciccarelli and Mojon (2005) report that a common component or factor explains a large proportion of the variation in national inflation rates. Building on this study, Mumtaz and Surico (2006) have found that the common component explains a greater proportion of quarterly inflation movements in these countries after the mid-1980s relative to the period before that.

The main theme in the findings of all these papers is that (an) international common factor(s) explain some significant amount of variation in headline inflation rates across countries. This is an important finding as it argues that inflation has become more of an international phenomenon. In other words, the international factors (developments) are now affecting the national headline inflation rates in a more systematic way. What causes this 'internationalisation' of national inflation rates is a very important question. Two possible explanations for these finding are as follows. First, the increased comovement in inflation rates could reflect adoption of similar monetary policy across the industrialised countries. Clarida, Gali and Gertler (1998) argue that the central banks of Japan, Germany and the United States have pursued an implicit form of inflation targeting since the beginning of the 1980s; and during the 1990s, inflation targeting has been explicitly adopted in a number of industrialised countries. Second, it could reflect the increased integration of global product and factor markets, which subjects the relative prices of similar products in different countries to common demand and cost shocks. In this paper we test for the second explanation.

One explanation for the relative price comovements comes from the imported inputs that are used in production of goods. A simple cost-pressure theory of relative prices would suggest that as long as it is not too difficult for new firms to enter a market, prices in a sector should ultimately be a function of the production cost in that sector and some profit margin. The costs fall if productivity increases are greater than wage growth, or if the price of imported inputs falls. So one would expect relatively smaller price increases in sectors that have relatively higher rates of technological progress, or in sectors that import larger proportion of inputs from other countries where prices are falling.

This has important implications: since most technical advances are easily copied, and cheap imports are readily obtained, the relative size of cost pressures should be similar in developed countries (see Coleman (2007)). Therefore, the relative price changes should exhibit some common patterns (or factors) in these countries. We argue if such comovement is present, it may explain the observed comovement in headline inflation rates shown in Mumtaz and Surico (2006) and other papers.

We argue that the international common component may not necessarily be the ones that affect every single sector/product in different economies. The international component may also be product/category specific. For example, the international factors affecting rice prices across countries may be different than the international factors affecting car prices. Therefore, estimating international factors that are common for all categories may underestimate the true nature and the size of the international factors in explaining cross-country comovements in inflation rates. To answer this, we explicitly estimate a model that includes factors that are category/product specific. Our hypothesis is as follows. If it is indeed the adoption of similar monetary policy rather than global integration of product markets that is driving the international comovement in inflation rates, then we should not find evidence for comovement in product category inflation rates. For example, if both the United States and the United Kingdom follow loose monetary policy, we should expect headline inflation to rise in both countries, but inflation rates of each product category – eg clothing or household equipment – need not rise in tandem. By contrast, if the international comovement in inflation rates is mainly driven by integration of global markets, which subjects prices of similar products to global cost and demand shocks, we would expect to see cross-country comovement in product category inflation rates; and this comovement should be greater for internationally traded products and products intensive in internationally traded inputs. For instance, if clothes are freely traded across countries, demand or technology shocks that are specific to clothing industry should show up as comovement in clothing inflation rates. If, on the other hand, clothing markets are not globally integrated, and clothing prices are subject to local demand and technology shocks, we would not necessarily observe comovement in clothing inflation rates. In fact, we find that when we include the international product/category specific factors, these factors tend to dominate the ‘global factor’.

To address this issue, we extend Mumtaz and Surico (2006) and Monacelli and Sala (2009) analyses to examine the cross-country comovement of product category inflation rates which

comprise the consumer prices index (CPI) of fourteen industrialised economies. Our data set consists of quarterly headline CPI and price indices of 28 product categories which are matched across all countries included in the sample, and spans the period of 1998 Q1 to 2008 Q2. Using a Bayesian dynamic factor analysis, we decompose fluctuations in quarterly inflation rates into a world factor, country-specific factors, and product/category-specific factors. The world factor captures the common pattern in inflation rates across all product categories across all countries. Country-specific factors capture the common pattern in inflation rates across all product categories within the same country. Finally, the category-specific factors capture the common pattern in inflation rates across countries for the same product categories (eg clothing). Our data is not as disaggregated as Monacelli and Sala (2009) at the product level. However, our data set has a few other advantages: first, we have a larger number of countries. Second, the product level data we have are balanced and refer to almost the same products across countries, which enable us to estimate the product/category level international factors.[1]

There are a number of interesting findings emerging from our analysis. First, product factors explain a significant proportion of fluctuations in quarterly inflation rates for products that are intensive in primary commodities; but this is less evident for other traded goods. Second, both the world factor and product factors have become more significant in explaining the fluctuations in quarterly inflation rates for most product categories. Finally, the sharp pickup in inflation rates during 2007-08 was captured by our estimated world factor. However, this factor does not show any variation apart from this 2007-08 period.

The remainder of the paper is organised as follows. Section 2 describes our data set. Section 3 explains the factor model approach used in our analysis. Section 4 presents the results. Section 5 discusses the implications and limitations of our analysis. Section 6 concludes.

[1] Another strand of the literature attempts to tackle this issue by looking at the relationship between inflation rates in individual countries and some estimates of the global output gap; but evidence from this literature is mixed. For instance, Borio and Filardo (2007) argues that a global output gap measure helps explain the behaviour of inflation for a range of advanced countries. Ihrig, Kamin, Lindner and Marquez (2007), however, argues that Borio and Filardo's results are not robust to plausible alternative inflation equation specifications. Calza (2008) finds little evidence that global output gap measures have predictive power for consumer price inflation in the euro area. Thus, the evidence on the link between domestic inflation and global economic slack remains, at best, inconclusive, and there are a number of conceptual and empirical reasons why global influences on domestic costs and prices may not be captured by a measure of the global output gap. These findings, however, do not necessarily imply that increased trade integration has had no impact on domestic inflation dynamics. Thus, our paper seeks to shed light on the impact of globalisation on inflation dynamics using an alternative empirical strategy. A very similar research in terms of the methodological approach has emerged on the effects of globalisation on business cycle synchronisation. Kose, Otrok and Whiteman (2003), for example, decompose the fluctuations on key macro variables into a global, country-specific and region-specific factors. Crucini, Kose and Otrok (2008) examined the G7 business cycles in a similar fashion.

2 Data

Our data set consists of the headline CPI for fourteen advanced economies and the price indices for 28 product categories which comprise each country's CPI. The fourteen advanced economies included in our sample are the United States, United Kingdom, Norway, Canada, and ten euro-area countries (Germany, Belgium, Spain, Finland, France, Greece, Ireland, Italy, Netherlands, and Austria). The data are quarterly averages of the monthly series that run from 1998 Q1 to 2008 Q2. The raw CPI headline and product category indices are seasonally adjusted (using Census X12), and transformed into quarterly log differences. They are then normalised to have zero mean and unit variance before the factor analysis.

In order to examine the extent to which global integration of product markets affect the comovement of inflation rates, we created a data set of product category price indices that are matched across countries. This data set allows us to estimate the world factor, the country factors and the product category factors separately. In some countries, a certain product category is included in calculation of the headline CPI but not in others: such product categories were excluded from our sample. In other cases, a synthetic product category price index was created by using a weighted sum of several product category price indices from the raw data in order to create a match with other countries' data. Furthermore, some product categories were dropped from our sample because their prices are regulated in some countries and hence are changed only infrequently: examples of such product categories include water and electricity. Having gone through this procedure, we end up with the price indices of 28 matched product categories, which are listed in Table A in the annex. Thus, our data set includes a total of 406 price series, consisting of 29 matched price series (headline CPI and 28 product categories) for the fourteen countries.

By construction, each of the matched product categories should contain a *similar* set of goods and services in each country in our sample, such that they can reasonably be expected to be subject to similar product-specific demand and cost shocks if their product markets are globally integrated. But clearly, the products included in each category would not be exactly the *same* across countries: for instance, 'fish' included in the UK CPI basket are different from 'fish' included in the US CPI basket. The total weights of these product categories account for about 45% of the headline CPI on average for countries included in our sample

(Table B in the annex).

3 Methodology

Consider a panel of international inflation series $\pi_{i,j,t}$ where the subscript i indexes the country, j indexes the product category, and t denotes the time dimension: so $\pi_{i,j,t}$ is the inflation rate of product category j in country i at time t. We assume that each inflation series $\pi_{i,j,t}$ can be described by the following dynamic factor model:

$$\pi_{i,j,t} = \beta_i^c F_{i,t}^c + \beta_j^g F_{j,t}^g + \beta_{i,j}^w F_t^w + \nu_{i,j,t} \quad \textbf{(1)}$$

where F^c denotes the country-specific factor which captures the common movement in inflation series of different products within the same country; F^g denotes the product-specific factor which captures the common movement in inflation series of the same product across countries; and F^w denotes the common 'worldwide' movement across inflation series of all products in all countries. The country, product and world factor loadings are denoted by β^c, β^g, and β^w, respectively, while $\nu_{i,j,t}$ is the error term. Neely and Rapach (2008) and Mumtaz and Surico (2006) allow time-variation in factor loadings. We do not go down that route for two reasons. First, the time series dimension of our sample is small which matters for time variation in factor loadings. Second, this would have increased the computational burden immensely.[2]

The three unobserved factors F^c, F^g, and F^w are assumed to follow an autoregressive process of order P (4 in our case):

$$F_t^k = c^k + \sum_{l=1}^{P} \rho_t^k F_{t-l}^k + e_t^k \quad \textbf{(2)}$$

where $k = \{c, g, w\}$. Finally the error term $\nu_{i,j,t}$ follows an autoregressive process too, $AR(4)$.

$$\nu_{i,j,t} = \sum_{i=1}^{P} \rho_{i,j} \nu_{i,t-i} + e_{i,j,t} \quad \textbf{(3)}$$

[2]Our full sample estimation takes just under six days in the fixed factor loading version that we present in this paper.

The model described in equations **(1) - (3)** can be estimated by the Bayesian methods with Gibbs sampling. Gibbs sampling is a Markov chain Monte Carlo (MCMC) method for approximating joint and marginal distributions by sampling from conditional distributions. We describe the conditional prior and posterior distributions in detail in the appendix. However, in summary our algorithm contains the following steps:

1. Conditional on a draw for F^c, F^g and F^w, we simulate the AR coefficients and the variance of the shocks to equations **(2)** and **(3)**.
2. Conditional on a draw of F^c, F^g and F^w, we draw the factor loadings β^c, β^g and β^w.
3. Simulate F^c, F^g and F^w conditional on all other parameters above.
4. Go to step 1.

We use 30,000 Gibbs sampling replications and discard the first 26,000 as burn-in. So the results are from the remaining 4,000 iterations. The moments of model parameters vary little over the retained draws suggesting convergence.[3]

4 Results

This section presents the results from our analysis. First, the estimated world, country and product category factors are presented. Second, results from the variance decomposition are discussed to examine the extent to which the three factors explain the variance of the headline inflation rates and changes in product prices in the full sample, first subsample (1998 Q1-2003 Q1) and the second subsample (2003 Q2-2008 Q2). Finally, we consider the relative importance of the country, category and world factors in driving the *level* of price changes for different goods by constructing indicators.

4.1 Description of factors

Charts 1, 2, and 3 in the annex show the estimated world, country and product category factors for quarter-on-quarter inflation rates, respectively. The black lines show the median of the last

[3]These results are available on request.

4,000 replications from the Gibbs sampling. The red lines show the upper and lower quartiles of these replications. The world factor captures the common movement across price indices of all product categories (and the headline CPI) in all countries in the sample. The country factors capture the common movement across price indices of all product categories and the headline CPI within each country. The product category factors capture the common movement of the same product category prices across all countries in the sample.

Our methodology does not allow us to distinguish between the structural shocks driving these factors. However, economic theory suggests a number of possible interpretations of these factors. For instance, the world factor could be capturing global demand and supply shocks; and cross-country similarities in monetary policy. The country factors could be capturing country-specific demand and supply shocks; changes in taxes; idiosyncratic monetary policy shocks; and exchange rate movements. The product category factors could be capturing product-specific demand and supply shocks. Thus, a strong role played by the world factor in explaining price movements would be consistent with the hypothesis that similar monetary policy is behind the increased comovement in inflation rates across countries. Conversely, strong product category factors would be consistent with the hypothesis that globalisation of product markets is driving greater comovement in inflation rates.

Chart 1, which plots the world factor, shows very clearly that the pickup in inflation during 2007-08 was indeed a global phenomenon affecting several countries and several product categories in our sample. However, Chart 2 shows that in a number of countries in our sample – eg Belgium, Canada, Finland, France, Italy, the United Kingdom and the United States – country-specific factors were also pushing up inflation rates during this period. Chart 3 shows that certain food items – such as bread, dairy, oil and fats, and sugar – saw price increases in many countries in our sample: this is consistent with the fact that food and energy contributed strongly to the rise in inflation rates in advanced economies during 2007-08.

As Chart 1 shows, the world factor is fairly precisely estimated. The precision with which country-factors are estimated varies from country to country (see Chart 2). For instance, the country factors of Belgium, Canada, Greece and Ireland are not as precisely estimated as in other countries. Although one would expect the country-specific factor to matter less in small, highly open economies compared to large, relatively closed economies, the significance of

country-specific factors is not entirely explained by countries' openness to trade: for instance, the country-specific factor for Netherlands, which is small and highly open to trade, is quite precisely estimated. It is also worth noting that country-specific factors are significant in most euro-area countries, suggesting that common monetary policy in the euro area interacts with heterogeneous country-specific conditions to give rise to inflation dynamics in each of the member countries.

Chart 3 shows that the precision with which product category factors are estimated differs from category to category. However, it displays some interesting patterns. Confirming our prior, the products which are intensive in globally traded primary commodities – such as most food items (bread, meat, fish, dairy, oil and fats, fruit, vegetables, sugar and coffee), vehicle fuels and jewellery – display strong product-specific factors. This suggests that developments in commodity markets – which are globally integrated – indeed play a significant role in causing common short-run movements in inflation rates across countries. However, some of the heavily traded manufactured goods – such as clothing, footwear, furniture, utensils, computer and vehicles – do not display strong product factors, although audio visuals has a strong product factor. As expected, less traded items such as accommodation and personal care do not display significant product factor, although the strong product factor found for laundry is rather puzzling.

4.2 Variance decomposition

This section summarises the results from the variance decomposition analysis. With orthogonal factors, the variance of $\pi_{i,j,t}$ can be written as:

$$var(\pi_{i,j,t}) = \left(\beta_i^c\right)^2 var\left(F_{i,t}^c\right) + \left(\beta_j^g\right)^2 var\left(F_{j,t}^g\right) + \left(\beta_{i,j}^w\right)^2 var\left(F_t^w\right) + var\left(v_{i,j,t}\right) \qquad \textbf{(4)}$$

So we can decompose the variance of each inflation series $\pi_{i,j,t}$ into the proportion explained by each of the three factors. Specifically, we compute the fraction of total variance explained by the country, product category, and world factors as $\frac{(\beta_i^c)^2 var(F^c)}{var(\pi_{i,j,t})}$, $\frac{(\beta_j^g)^2 var(F^g)}{var(\pi_{i,j,t})}$, and $\frac{(\beta_{i,j}^w)^2 var(F^w)}{var(\pi_{i,j,t})}$, respectively. Using these formula, we calculate the median variances explained by each factors for each subcategory in each country (for 406 series). We do this for two subsamples (1998 Q1–2003 Q1 and 2003 Q2–2008 Q2) and the full sample.

Table C in the annex shows the cross-country average proportion of variances explained by each

factor for each product category inflation. The columns 'first, second and full' refer to the first and second subsamples, and the full sample respectively. For example, the first row of Table 3 shows the average proportion of variance in bread inflation explained by each factor in fourteen countries in our sample.[4] There are a few important patterns to note. First, the product category factors (which can be regarded as category-specific international factors) are found to be very important (and the most important factor) in explaining the variations in most product category inflation rates across countries. Second, the world factor seems to explain very little of the variation in product category inflation rates. These two findings suggest the importance of the category-specific factors at relative price level. Third, the country-specific factors are still important in most cases, though not as important as the product category factors. Finally, as one would have expected, the product category factors explain a greater proportion of variances for those goods that are more traded than the others. Most of the food-related items (such as meat and dairy), audio-visual prices and vehicle fuel are examples of this.

Focusing on specific products, it is noteworthy that product category factors explain a very high proportion of the variances in inflation for products intensive in primary products – such as food, vehicle fuels and jewellery. Other highly traded goods, such as audio visuals, also display a strong product category factor. Thus, there is some evidence that the relative prices of certain internationally traded goods – and goods that are intensive in internationally traded inputs – do comove across countries. On the other hand, there are also a number of highly traded goods (eg clothing, footwear and computer) for which the product category factor explains very little of the inflation variation.

Table D in the annex shows the average proportion of inflation variances explained by each factor for each country in our sample. For example, columns two, three and four of the table show the average variance explained by the country factor in the first subsample, second subsample and the full sample, respectively. The first row of the table shows that the average variation in German subcategory inflation series explained by the country factor is 22% in the first subsample; but this falls to 13% in the second subsample and is 14% in the full sample. As this table shows, the product category factors explain the largest share of variation in almost all countries. Moreover, the variation explained by this factor increases in the second subsample in most countries. The country factors remain important for most countries, although they have declined noticeably in

[4]Results for individual country are available upon request.

importance in the second subsample for some countries, eg Germany, Belgium, Canada and Norway. Finally, the world factor explains very little of the variation in inflation rates on average.

4.3 Indicators

In this section we consider the relative importance of the country, category and world factors in driving the *level* of inflation for different goods. We conduct this exercise by constructing the following indicators for each inflation series in our panel. These indicators are calculated as:

$$\begin{aligned}
\hat{Y}^{C}_{i,t} &= \hat{\Phi}_i F^{C}_t \\
\hat{Y}^{GC}_{i,t} &= \hat{\Phi}_i F^{C}_t + \hat{\Upsilon}_j F^{G}_{j,t} \\
\hat{Y}^{GCW}_{i,t} &= \hat{\Phi}_i F^{C}_t + \hat{\Upsilon}_j F^{G}_{j,t} + \hat{\lambda}_k F^{W}_t
\end{aligned}$$

where $\hat{\Phi}_i$ represents estimated factor loadings on the country factors F^{C}_t, $\hat{\Upsilon}_j$ are the estimated factor loadings on the category factors $F^{G}_{j,t}$ and $\hat{\lambda}_k$ are the estimated factor loadings on the world factor F^{W}_t. In the charts below the black lines represent actual data, $\hat{Y}^{C}_{i,t}$ is shown as the red lines. The light blue lines represent $\hat{Y}^{GC}_{i,t}$ while the dark blue lines depict $\hat{Y}^{GCW}_{i,t}$. A comparison of the data and $\hat{Y}^{C}_{i,t}$ provides information about the role played by the country factor in driving the *level* of inflation. A comparison of $\hat{Y}^{C}_{i,t}$ and $\hat{Y}^{GC}_{i,t}$ provides information on the importance of the category factor – a large gap between the red and the light blue lines would suggest that the category factor plays an important part in driving inflation fluctuations. Similarly, a comparison of $\hat{Y}^{GC}_{i,t}$ and $\hat{Y}^{GCW}_{i,t}$ provides information on the relative importance of the world factor – a large difference between the dark and the light blue lines would suggest that the world factor plays an important role in determining the level of inflation.

Charts 4, 5, 6 and 7 plot the estimated indicators for a selected set of food items – ie bread, dairy products, meat and sugar. Note that, in general, there is a sharp increase in inflation for these categories towards the end of the sample period and then a fall in the last quarter. Consider Chart 4. The country factor plays a limited role with the red line flat for almost all countries. The increase in bread prices in 2001-02 is largely explained by the bread-specific category factor with little difference between the light and the dark blue lines over this period. Both the category and

the world factors appear to be important in explaining the sharp increase in bread prices towards the end of the sample, with the world factor particularly important in countries such as Germany, Canada, Finland and France. Prices for dairy products show a similar pattern with the increase in 2008 driven by the dairy category factor. The largest movement in meat prices occurred during the years 2000-02 for a number of countries. The sharp increase over this period appears to be largely driven by the meat category factor. In contrast the increase in meat prices seen in 2008 in Finland, Ireland, Austria and the United Kingdom was driven to a large extent by the world factor. Sugar price inflation also rose in 2008 and Chart 7 shows that this was driven primarily by the world factor. Chart 8 plots the estimated indicators for vehicle fuel. For all countries recent fluctuations in vehicle fuel inflation have been driven almost entirely by the category-specific factor. In particular, the increase in fuel prices in 2007 and their subsequent fall is explained almost entirely by the fuel-specific factor.

These results are consistent with the findings in Ciccarelli and Mojon (2005) and Mumtaz and Surico (2006) which suggest an increasingly important role for comovement in national inflation rates. Our estimates show that this pattern is also reflected at the disaggregated level with cross-country and good-specific comovement important over the last decade.

5 Discussion

So what does our analysis say about the drivers of increased inflation comovement found by previous research? First, there is some evidence supporting the 'correlated monetary policy' hypothesis. In particular, the world factor is fairly precisely estimated and suggests that the sharp rise in inflation during 2007-08 was a global phenomenon affecting a large number of price series included in our sample. We note, however, that the world factor may be overstating the cross-product, cross-country inflation comovement, because of the way our data set is constructed. In particular, we have dropped product categories which account for more than half of the CPI weight from our sample in order to construct a matched data set. One consequence of this is the overrepresentation of food items in our sample. Since food prices tend to be strongly correlated across countries and across food product categories, this sample selection may have led to the overstatement of the role of the world factor.

Second, the evidence supporting the globalisation hypothesis appears to be mixed. On the one

hand, product category factors account for a significant share of variations in price movements for commodity-intensive products, such as food and vehicle fuels; and the importance of product factors appear to have increased in the second subsample relative to the first. On the other hand, product category factors do not appear to account for a large share of variations in price movements for heavily traded manufactured goods.

One interpretation of our results is that the only markets which appear to be globally integrated are the global commodity markets, and developments in these do exert strong influence on inflation dynamics in advanced economies. Outside these markets, global integration of product and factor markets – and hence product-specific demand and cost shocks – play a limited role in influencing inflation dynamics in advanced economies, despite the increase in international trade over the last decade. This could, for example, reflect the 'pricing to the market' behaviour of wholesalers and retailers who adjust their margins according to the local market conditions, at least in the short run.

Equally, however, there are a number of reasons why the estimated product factors may not be fully capturing the impact of product and factor-market integration on inflation dynamics. First, exchange rate movements could be reducing the estimated comovement of product price indices across countries. For instance, it is possible that the product category factor becomes insignificant even if the product markets are perfectly integrated such that the law of one price holds across countries. This can happen if exchange rates are volatile relative to the product-specific demand and cost shocks. As mentioned previously, exchange rate movements are likely to be captured by country-specific factors. Second, the relative unimportance of product factors for heavily traded manufactured goods could simply reflect data limitations. As discussed in Section 2, product categories are matched in order to ensure that they contain similar basket of goods and services. However, the differences in goods and services contained in each product category, and the weight assigned to each item within the basket, could be quite significant. If the items contained in each category are quite heterogeneous, then they may not be subject to similar product-specific shocks. Thus, the estimated product category factor may be insignificant even if product markets are actually integrated.

6 Conclusions

In this paper we estimated a dynamic factor model for a balanced panel of disaggregated inflation series for 28 different components of the CPI from fourteen different countries. In particular, we estimated a world factor, country-specific factors and product (good-specific) factors. The world factor captures the common pattern in inflation rates across all product categories across all countries. Country-specific factors capture the common pattern in inflation rates across all product categories within the same country. The category-specific factors capture the common pattern in inflation rates across countries for the same product categories (eg clothing).

Our results suggest that product category factors explain a significant proportion of fluctuations in quarterly inflation rates for products that are intensive in primary commodities; but this is less evident for other traded goods. We also find that both the world factor and product category factors have become more significant in explaining the fluctuations in quarterly inflation rates for most product categories. Finally, the sharp pickup in inflation rates during 2007-08 was captured by our estimated world factor, but in some countries the rise in the inflation rate also reflected country-specific factors.

Appendix: Gibbs sampling algorithm for a dynamic factor model

Consider the estimation of the following dynamic factor model

$$\pi_{i,j,t} = \beta_i^c F_{i,t}^c + \beta_j^g F_{j,t}^g + \beta_{i,j}^w F_t^w + v_{i,j,t} \quad \textbf{(A-1)}$$

$$F_t^k = c^k + \sum_{l=1}^{P} \rho_t^k F_{t-l}^k + e_t^k \quad \textbf{(A-2)}$$

where $k = \{c, g, w\}$.

$$v_{i,j,t} = \sum_{i=1}^{P} \rho_{i,j} v_{i,t-i} + e_{i,j,t} \quad \textbf{(A-3)}$$

where

$$\begin{aligned} var\left(e_t^k\right) &= Q_k \\ var(e_{i,j,t}) &= R \end{aligned}$$

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). The covariance of the states ($P_{0/0}$) is set equal $I_{0.1}$ where I_n denotes a diagonal matrix with n on the main diagonal.

Starting values for the factor loadings are also obtained from the PC estimator. We assume a flat prior for the factor loadings.

AR coefficients

The prior for the AR coefficients is Normal and is defined as

$$\rho_0 \sim N(\bar{\rho}, \bar{V})$$

where $\bar{\rho}$ is a 4×1 vector of zeros and $\bar{V} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.75 & 0 & 0 \\ 0 & 0 & 0.5 & 0 \\ 0 & 0 & 0 & 0.25 \end{pmatrix}$. This reflects a stronger belief that the coefficients on higher lags are equal to zero. The prior mean for the constant is zero while the prior variance is set equal to 1.

Hyperparameters

We assume a flat prior for Q and R.

Simulating the posterior distributions

Factors

The conditional distribution of the factors F_t is linear and Gaussian:

$$F_T \backslash X_{i,t}, R, Q \sim N\left(F_{T\backslash T}, P_{T\backslash T}\right)$$
$$F_t \backslash F_{t+1,} X_{i,t}, R, Q \sim N\left(F_{t\backslash t+1,F_{t+1}}, P_{t\backslash t+1,F_{t+1}}\right)$$

where $t = T - 1, ..1$, X denotes the inflation data transformed to account for serial correlation in $v_{i,j,t}$.

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

As shown by Kim and Nelson (1999), 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:

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

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

Because of the AR form for $v_{i,j,t}$ the state space has to be 'augmented' such that the factors are transformed to account for serial correlation.

Elements of R

Conditional on a draw for the factors and the factor loadings and the autoregressive coefficients, the diagonal elements R_{ii} are drawn from the following inverse gamma distribution:

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

where

$$\bar{R}_{ii} = \hat{e}'_{i,j,t} \hat{e}_{i,j,t}$$

Elements of β

Conditional on the factors, the autoregressive coefficients The factor loadings are sampled from

$$\beta_i \sim N\left(\bar{\beta}_i, \bar{M}_i\right)$$

where $\bar{\beta}_i$ and $\bar{M}_i$ represents an OLS estimate of the factor loading and its variance.

$$\bar{\beta}_i = \left(F_t^{*\prime} F_t^*\right)^{-1} \left(F_t^{*\prime} X_{i,t}\right)$$

$$\bar{R}_{ii} \left(X_{i,t}^{\prime} X_{i,t}\right)^{-1}$$

where F_t^* and $X_{i,t}$ represent factors and inflation data (respectively) transformed to account for serial correlation.

AR coefficients

Given an estimate for the factors, factor loadings, R and Q, the model reduces to a series of simple autoregressive regressions. The conditional posterior for these is normal and described in detail in Kim and Nelson (1999).

Elements of Q_k

Conditional on factors, and the autoregressive parameters, the innovations to equation **(A-2)** are observable and elements of Q are drawn from the inverse gamma distribution.

Identification

The factor model in equations **(A-1)**, **(A-2)** and **(A-3)** suffers from rotational indeterminancy. That is, the sign and the scale of the factors and factor loadings is not identified seperately. In order to identify the scale we fix the magnitude of Q_k. Following Kose, Otrok, Whiteman (2003) we restrict the signs of some factor loadings to identify the signs. For example, the world factor is restricted to load positively on US headline CPI. The goods factor is restricted to load positively on prices of US goods. Finally, the country factor is restricted to load positively on headline CPI in each country.

Annex: Tables and charts

Table A: List of product categories

	UK and European countries	Canada	US
	CPI all items (harmonised)	CPI	CPI all urban sample (all items)
Bread	Bread and Cereals	Bakery and cereal products	Cereals and bakery products
Meat	Meat	Meat	Meats
Fish	Fish and seafood	Fish, seafood and other marine products	Fish and seafood
Dairy	Milk, cheese and eggs	Dairy products and eggs	Dairy and related products
Oil	Oil and fats	Fats and oils	Fats and oils
Fruit	Fruit	Fruit, fruit preparations and nuts	Fresh fruits
Vegetables	Vegetables	Vegetables and vegetables preparations	Fresh vegetables
Sugar	Sugar, jam, honey, chocolate and confectionery	Sugar and confectionery	Sugar and sweets
Coffee	Coffee, tea and cocoa	Coffee and tea	Beverages materials including coffee and tea
Juice	Mineral water, soft drinks and juices	Fruit juice	Juices and non-alcoholic drinks
Alcohol	Alcoholic beverages	Alcoholic beverages	Alcoholic beverages
Clothing	Garments	Clothing	Synthetic index consisting of: Mens' and boys' apparel Womens and girls apparel Infants' and toddlers' apparel
Laundry	Cleaning, repair and hire of clothing	Synthetic index consisting of: Dry cleaning Laundry services	Laundry and dry-cleaning services
Footwear	Footwear including repair	Footwear	Footwear
Furniture	Furniture and furnishings	Furniture	Furniture and bedding
Utensils	Glassware, tableware and household utensils	Non-electric kitchen utensils and tableware	Nonelectric cookware and tableware
Tools	Tools & equipment for household and garden	Tools and other household equipment	Tools, hardware and outdoor equipment and supplies
Domestic non-durables	Non-durable household goods	Synthetic index consisting of: Household chemical products Paper, plastic and foil supplies	Housekeeping supplies
Vehicles	Purchase of vehicles	Purchase of passenger vehicles	New and used motor vehicles
Vehicle spare parts	Spares parts and accessories for personal transport equipment	passenger vehicle parts and supplies	Motor vehicle parts and equipment
Vehicle fuel	Fuel and lubricants for personal transport equipment	Gasoline	Motor fuel
Vehicle maintenance	Maintenance and repair of personal transport equipment	passenger vehicle maintenance and repair services	Motor vehicle maintenance and repair
Audio visuals	Equipment for the reception, recording and reproduction of sound and pictures	Home entertainment equipment, parts and services	Video & audio
Computer	Information processing equipment	Computer equipment and supplies	Personal computers and peripheral equipment
Books	Books	Books (excl. textbooks) and other printed material	Recreational reading materials
Personal care	Personal care	Personal care	Personal care
Accommodation	Accommodation services	Traveller accommodation	Lodging away from home
Jewellery	Jewellery, clocks and watches	Synthetic index consisting of: Jewellery Watches	Jewelry and watches

Table B: Total weights of product categories included in our sample in each country's headline CPI index

Country	Total CPI weight
UK	41.00
Belgium	48.54
Germany	40.24
Ireland	42.21
France	47.99
Italy	54.40
Netherlands	42.82
Spain	52.33
Austria	44.64
Finland	45.61
Greece	45.65
Norway	49.48
Canada	38.76
US	35.00
Average	**44.91**

Table C: The average proportion of variances of product category inflation explained by each factor (per cent)

	Country			Category			World		
	First	Second	Full	First	Second	Full	First	Second	Full
Bread	19	20	19	11	37	35	1	4	4
Meat	11	13	12	46	42	40	1	2	2
Fish	16	14	14	4	9	9	1	1	1
Dairy	12	13	13	29	40	37	1	5	4
Oil	13	14	13	6	25	28	1	3	3
Fruit	10	7	7	19	21	20	1	2	2
Vegetables	5	4	4	40	34	33	1	1	1
Sugar	15	21	20	23	15	15	1	3	3
Coffee	16	14	13	32	43	43	1	1	1
Juice	19	23	23	8	14	14	1	3	3
Alcohol	8	18	18	7	5	5	1	3	2
Clothing	19	16	15	8	3	3	1	1	1
Laundry	10	10	10	13	10	9	1	1	1
Footwear	20	18	18	5	6	5	1	1	1
Furniture	20	15	15	5	6	6	1	1	1
Utensils	18	13	13	6	4	5	1	1	1
Tools	14	9	8	6	3	3	1	2	2
Domestic non-durables	11	16	15	12	12	11	1	2	2
Vehicles	14	6	6	5	5	5	1	3	3
Vehicle spare parts	11	10	10	11	18	17	2	2	2
Vehicle fuel	3	1	1	63	78	67	1	1	1
Vehicle maintenance	12	11	10	7	9	10	1	2	2
Audio visuals	10	4	4	17	41	33	1	2	2
Computer	9	3	3	6	8	8	1	1	1
Books	10	6	6	4	3	4	1	10	9
Personal care	22	28	26	5	3	4	1	1	1
Accommodation	9	7	7	8	4	4	1	1	1
Jewellery	12	4	4	9	44	43	1	2	2
Headline	12	14	14	28	31	28	1	2	2

Chart 1: World factor

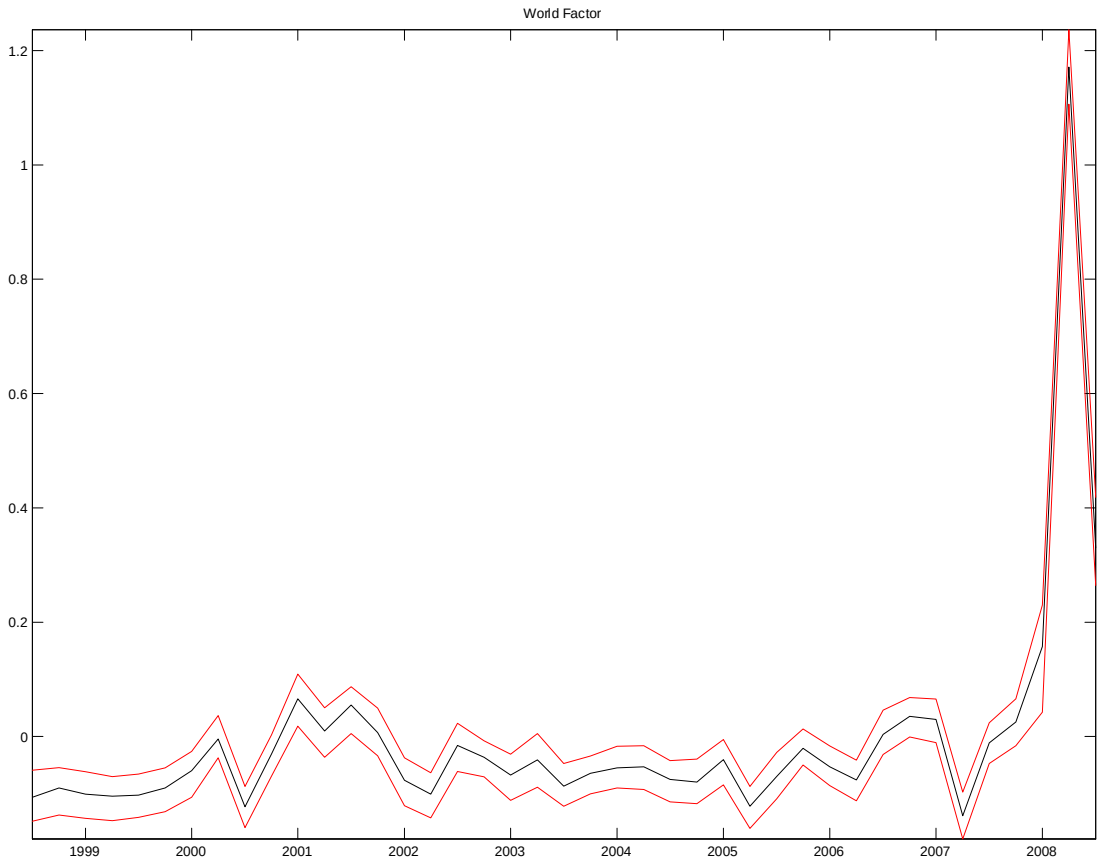


Chart 2: Country factors

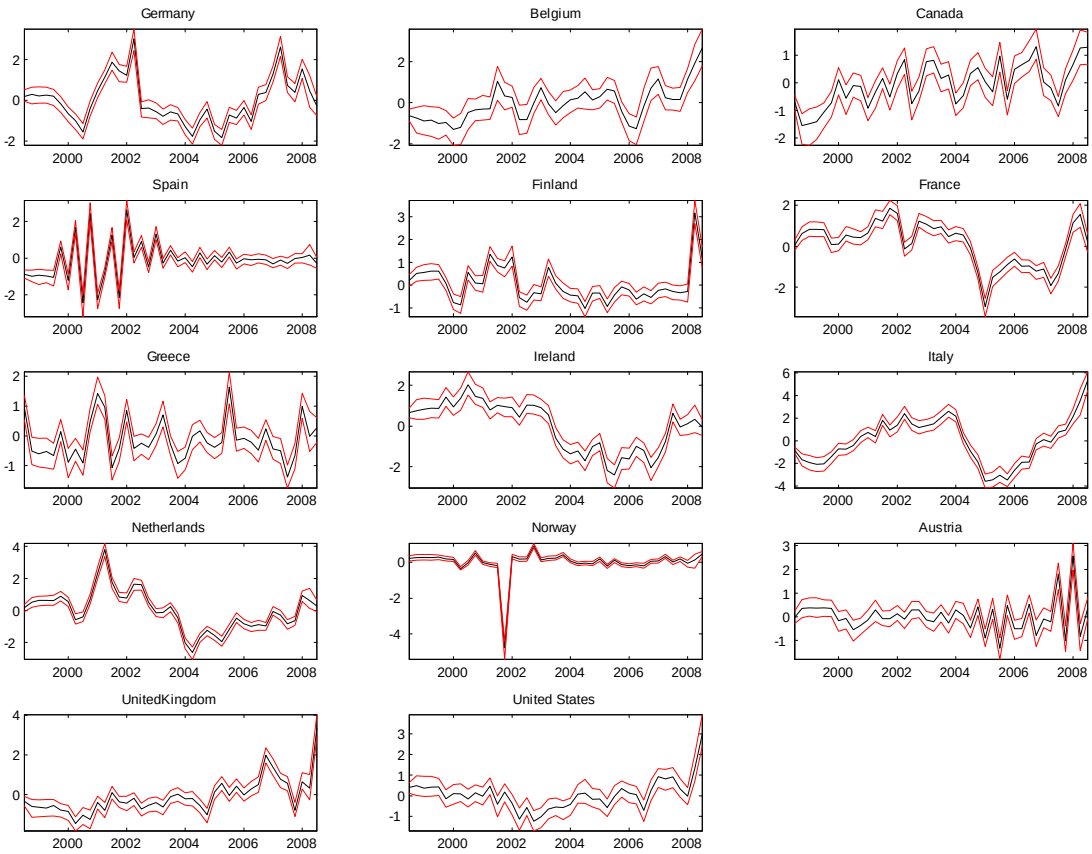


Chart 3: Product category factors

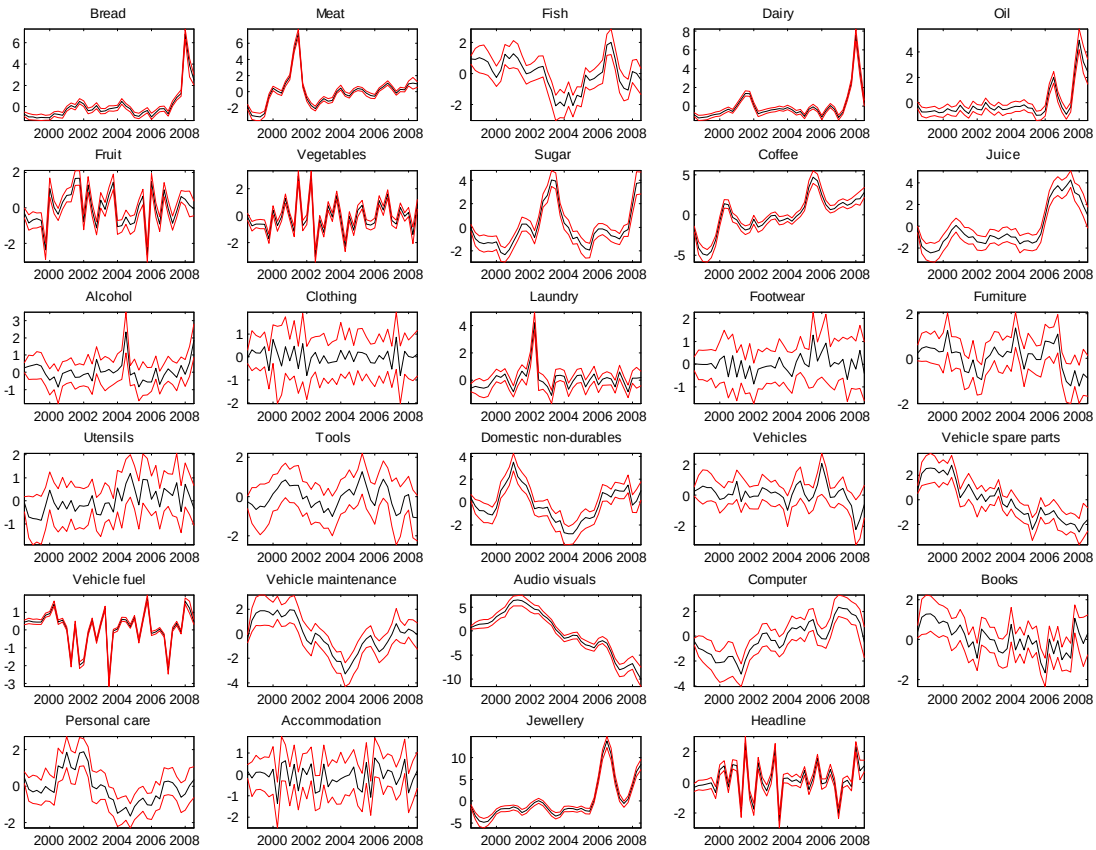


Table D: The average proportion of inflation variances explained by each factor, by country

	Country			Category			World		
	First	Second	Full	First	Second	Full	First	Second	Full
Germany	22	13	14	21	27	26	1	3	3
Belgium	14	3	3	13	26	25	1	1	1
Canada	13	9	8	10	10	10	1	3	2
Spain	12	10	10	16	28	26	1	2	2
Finland	8	9	9	17	14	13	1	3	3
France	9	12	10	25	27	26	1	3	3
Greece	5	6	5	10	14	13	1	1	1
Ireland	10	17	17	12	17	16	1	2	1
Italy	13	17	18	13	19	18	1	1	1
Netherlands	23	26	24	15	25	24	1	3	2
Norway	29	23	21	11	11	10	1	4	4
Austria	9	7	6	21	25	25	1	2	2
United Kingdom	7	9	9	16	18	17	1	3	3
United States	10	8	8	9	10	10	1	1	1

Chart 4: Indicators for bread prices (standardised)

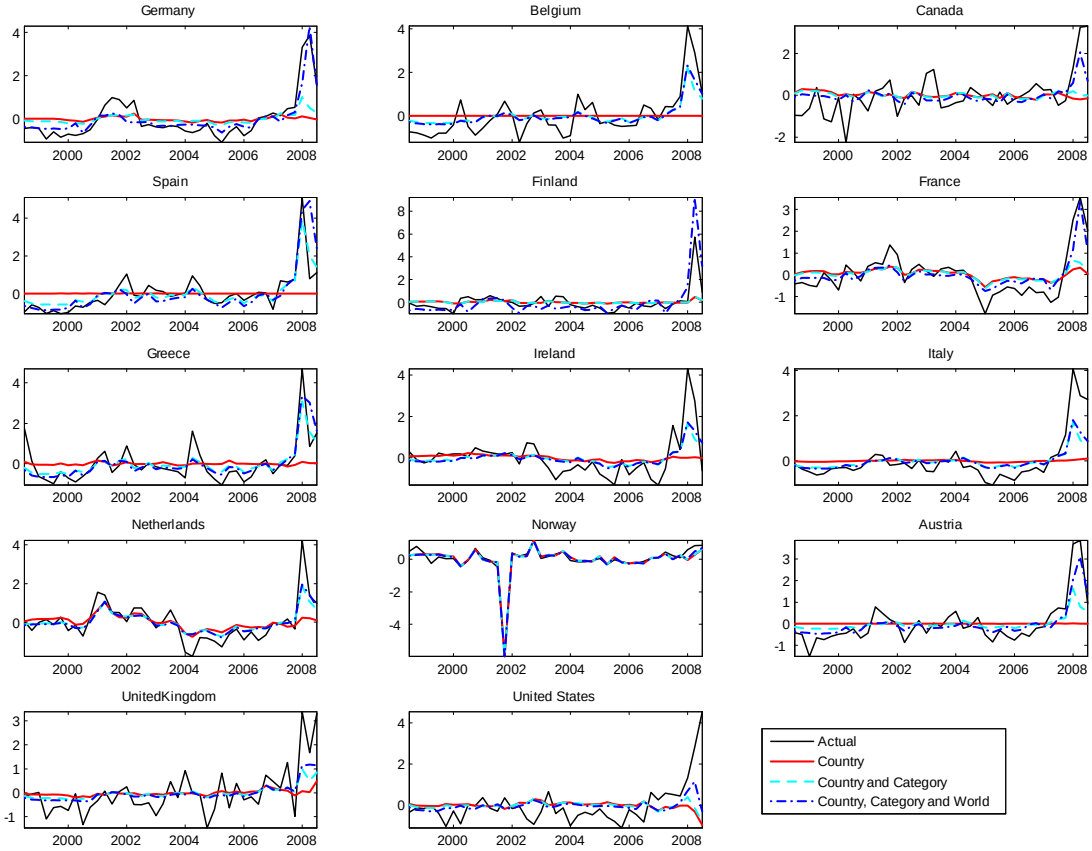


Chart 5: Indicators for meat prices (standardised)

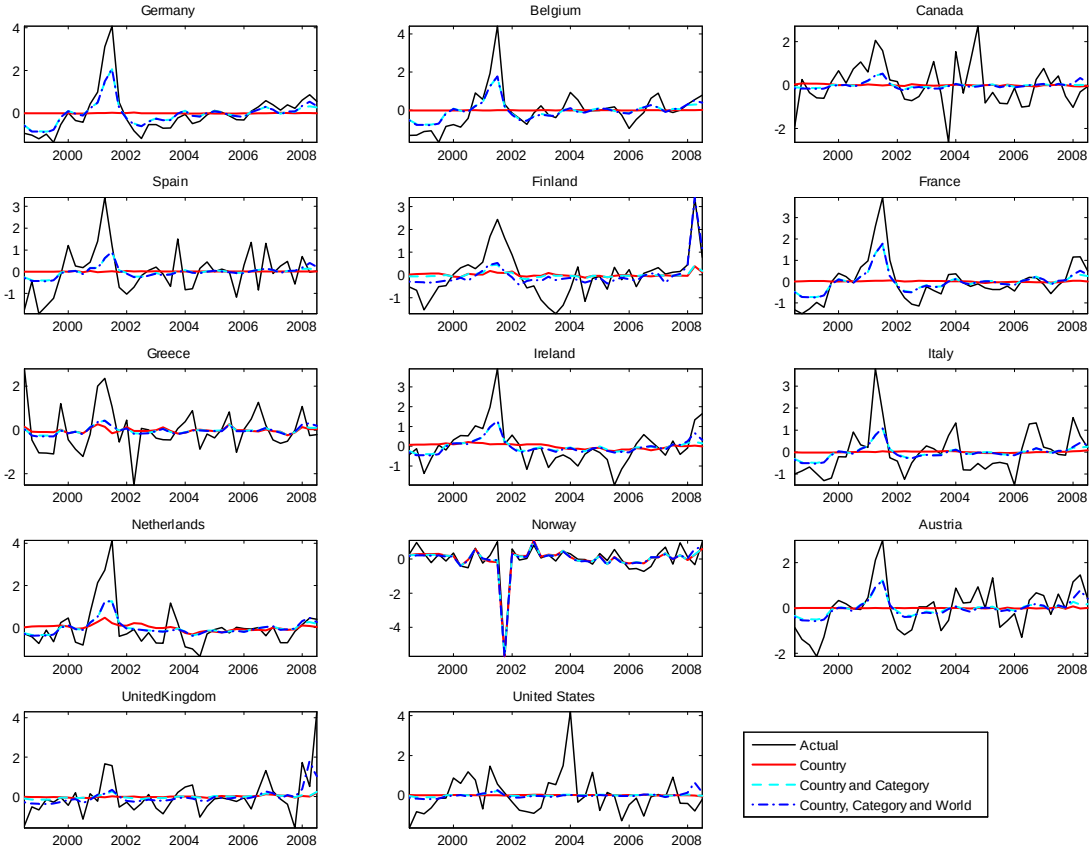


Chart 6: Indicators for dairy prices (standardised)

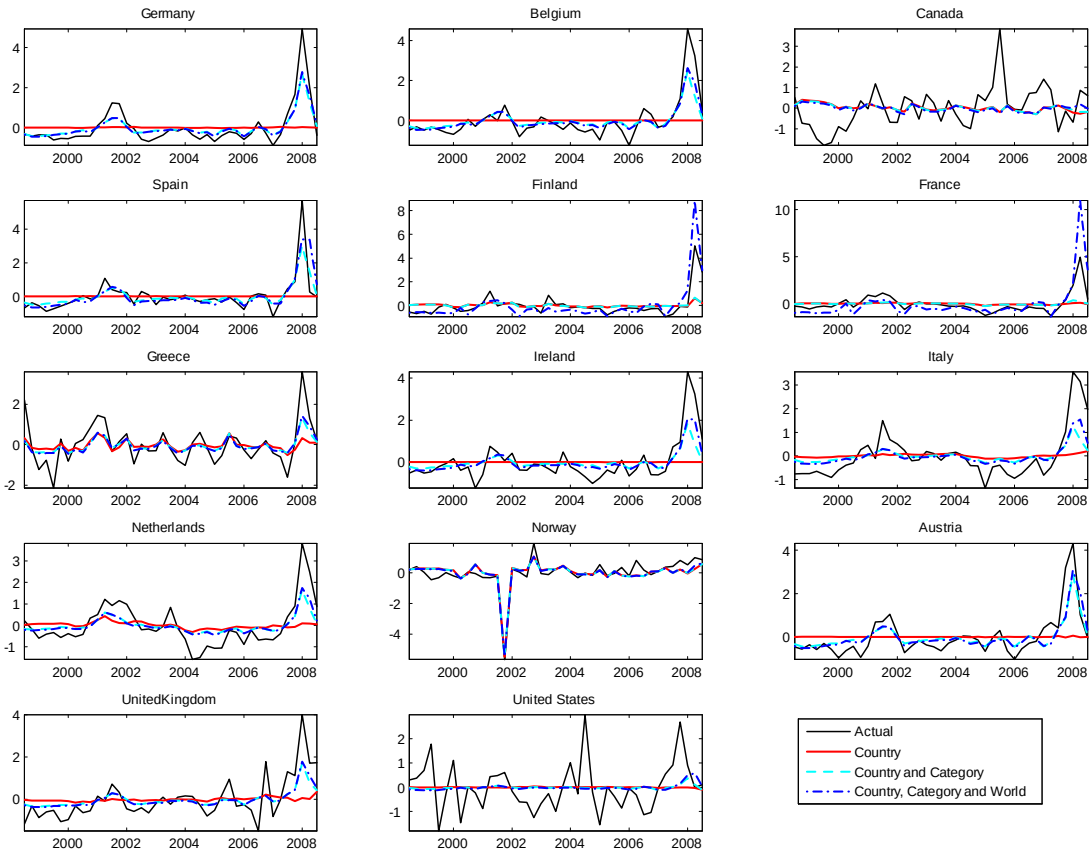


Chart 7: Indicators for sugar prices (standardised)

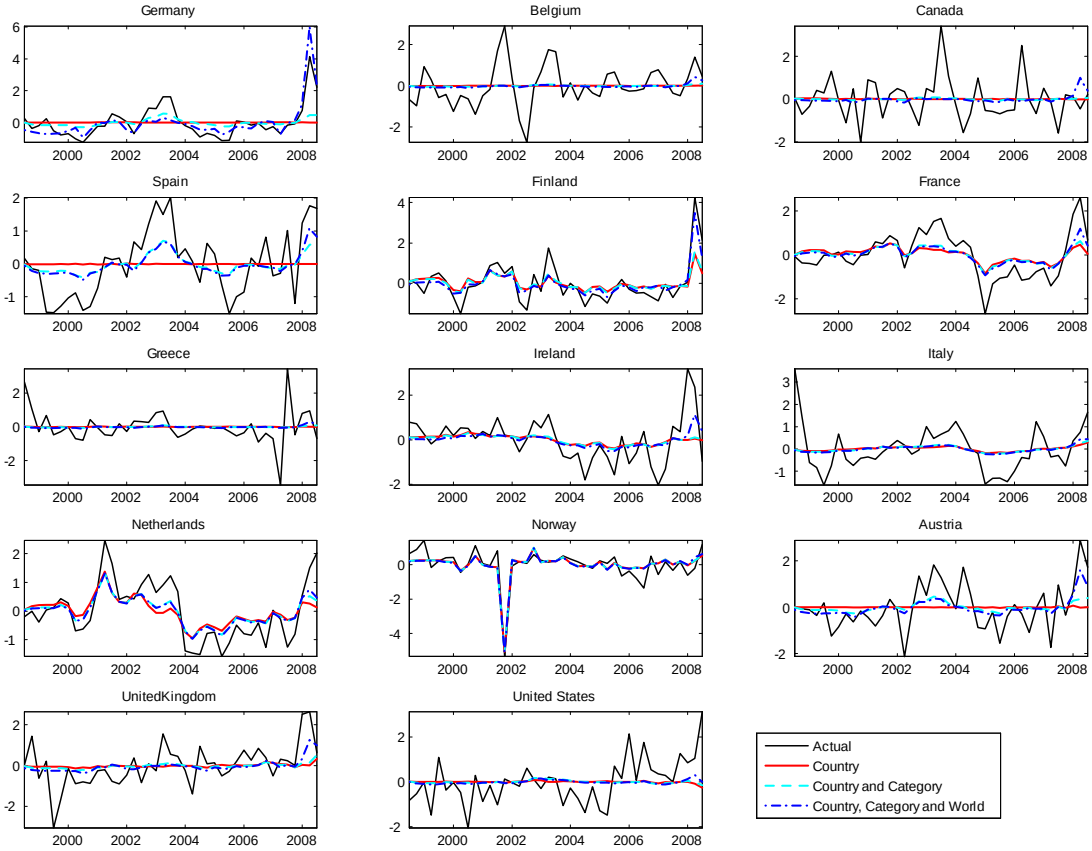
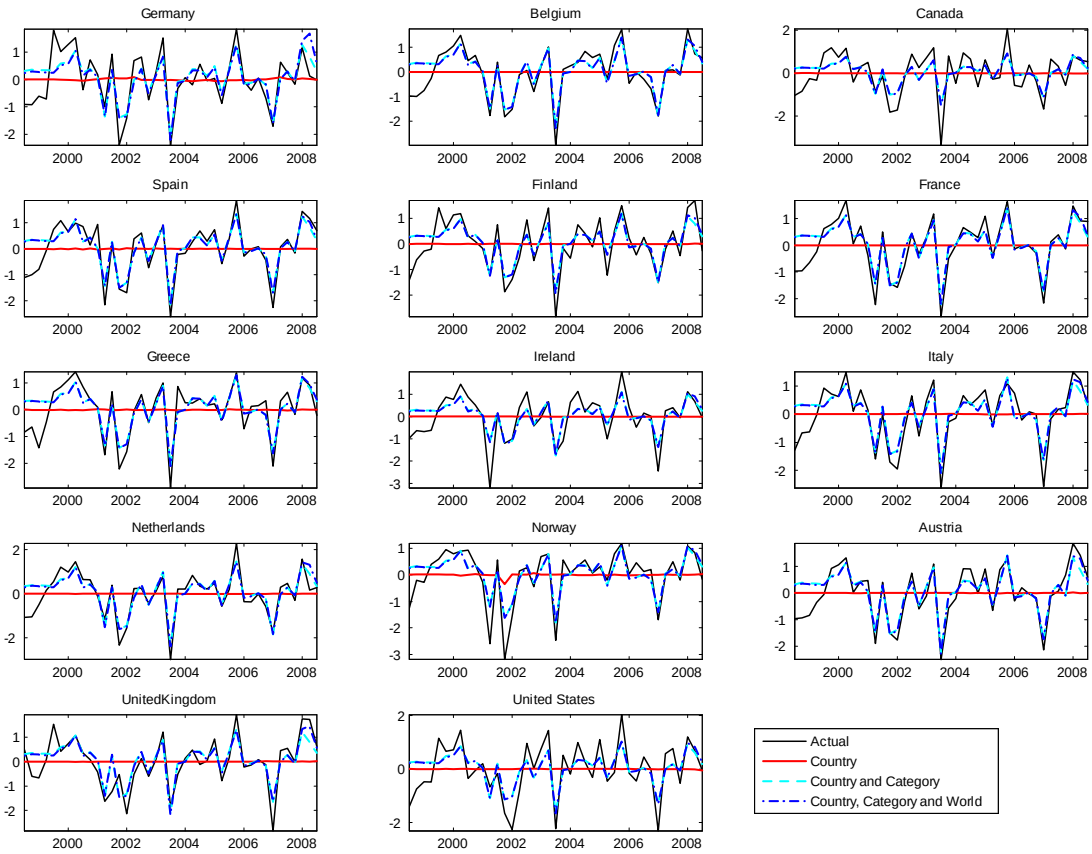


Chart 8: Indicators of vehicle fuel prices (standardised)



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