Common Shocks, Uncommon Effects: Food Price Inflation across the EU

Tim Lloyd, Steve McCorriston, Wyn Morgan and Evious Zvogu

Contributed Paper prepared for presentation at the 89th Annual Conference of the Agricultural Economics Society, University of Warwick, England
13 - 15 April 2015

Common Shocks, Uncommon Effects: Food Price Inflation across the EU

Tim Lloyd[1], Steve McCorriston[2], Wyn Morgan[1] and Evious Zvogu[1]

[1]University of Nottingham, UK
[2] University of Exeter, UK

Abstract:

Against the backdrop of recent price spikes on world commodity markets, retail food inflation has varied considerably across EU Member States despite the existence of a range of common policies and, for some Member States, a common currency. In this paper, focussing on retail bread inflation across 11 EU Member States, we investigate the extent and potential causes of the differences in the experience of food inflation. Using a structural VAR framework, we show that the contribution of world prices to the behaviour of retail bread prices shows significant differences across the EU Member States we cover. We show that differences in the functioning of the food sector (particularly barriers to competition and vertical control) appear to be correlated with the role played by world prices, highlighting the importance such structural features in commodity price transmission.

Keywords: Food Inflation; Structural Vector Autoregressive Models; Pass-through; Variance Decomposition

JEL Codes: C32, E31, Q02.

Common Shocks, Uncommon Effects: Food Price Inflation across the EU

1. Introduction

The commodity price shocks of 2007-2008 and 2011 triggered a broad range of concerns about retail food price inflation in both developed and developing countries, giving rise to a debate about the appropriate role for sectoral and macroeconomic policy in addressing the impact of world commodity prices on domestic food price inflation (IMF, 2011). It has also been widely observed that the behaviour of domestic retail prices can be markedly different across countries, even when triggered by a common exogenous shock. These differences are most notable when comparing the domestic food price inflation experience of developing and emerging economies with that of developed countries. Of course, there are many reasons for these differences, including the share and composition of food in household expenditure (Anand and Prasad, 2010), reliance on world markets and trade policy (Martin and Anderson, 2011) and the role of macroeconomic policy in addressing inflationary expectations (Gelos and Ustyugova, (2012) and Walsh (2011)). However, the historical record shows that food inflation experience can differ markedly, even for similar countries with an apparently unified market, common trade and sectoral policies and where macroeconomic policy is, to a very large extent, common. Food inflation in the EU is a case in point.

Set against the background of the spikes in global commodity prices, retail food price inflation has varied considerably across EU Member States. This is most obvious when comparing the EU-15 with the New Member States (following the enlargement in 2004): for the EU-15, average food price inflation for the 1990-2011 period was 2.26% while for the New Member States it was 7.66%. Perhaps of most interest in the context of the commodity shocks is the maximum rate of inflation between these two groups of countries; for any of the countries in the EU-15, food inflation reached a maximum in any one year of 22% (in the case of Greece), while for the New Member States, it reached a maximum of 188% (in the case of Bulgaria). Even within richer countries of the EU-15 group, the food inflation experience differed dramatically: in the UK, food price inflation reached a maximum rate of 12.3% while in France and Italy, the maximum annual rate of food price inflation reached around 6%. These different experiences of food inflation across the EU extend beyond the recent commodity price spikes of 2007-2008 and 2011. More generally, for most (but not all) EU Member States, average rates of food inflation tended to exceed non-food inflation, with the most notable feature being that food inflation tends to be more volatile than non-food inflation[1]. The volatility of food inflation and the differences that exist across EU Member States is reflected in the most recent experience: as world market prices have fallen, so too has average food inflation in the

[1] Associated with the experience of food inflation across developed and developing countries, there was also some debate on what monetary authorities should do to control food price inflation. See IMF (2011).

EU but with notable differences: annual food inflation in Finland for 2013 was 5.3%, for Germany 3.9%, for Norway 1%, Denmark 0.4% and Greece 0%.

While there may be some obvious reasons why food inflation has varied in these countries (some are more tied to world markets than others and have different exchange rates) much of the policy discussion within the EU has attributed the differences to the structure and intensity of competition in the food sector. Reflecting this, the EU Commission's *High Level Panel on Food Prices* sought to document and better understand the link between upstream and downstream prices, while Burkovite *et al.,* (2009) focussed on concerns about competition in the food chain. Indeed, the EU's *High Level Panel on the Functioning of the Food Chain* was created to address these issues among stakeholders while DG Competition (via the European Competition Network) recently documented anti-trust investigations in the food sector across all EU Member States addressing concerns that it was the lack of competition in the food sector that may (at least in part) be impacting on the functioning of the food sector and in turn, the transmission of shocks from world to domestic markets (ECN, 2012). The European Central Bank has also highlighted the potential links between possible differences in the retail and distribution sectors as factors that may explain the differences in the (food) inflationary experience across the EU. Notable here is ECB (2011) and ECB (2014) which also reflects recent research on comparative inflation across Eurozone countries, see Dhyne *et al.* (2006).

Against this background and the emerging policy concerns, the first objective of this paper is to address why the food price experience varied so markedly throughout the EU despite the commonality of the shocks. To account for the factors that may influence the different experiences throughout the EU and to avoid the compositional effects associated with the world commodity price index and retail food baskets, we estimate structural vector autoregressive models (SVARs) for a single vertical chain (world wheat prices through to retail bread prices). This is conducted for 11 EU Member States in which a full set of data is available.

The SVAR allows us to account not just for the link between world commodity (wheat) and retail (bread) prices but also to consider the role of other factors that may influence retail prices and the transmission from world to domestic markets, such as exchange rates and oil prices. Using the results from the 11 country models we (a) explore the differences in the dynamic profile of commodity price transmission via impulse response analysis and (b) employ a forecast error variance-decomposition to assess the relative contribution of each of the determining factors in food price inflation across countries. The results highlight considerable differences across the 11 EU Member States we analyse: the effect of a common 10% shock to world wheat prices leads to a 2% rise in bread prices on average, with the UK response being approximately eight times greater than that in France. Similarly, world wheat prices are estimated to account for 27% of the total variation in domestic retail bread prices on average, with the corresponding estimates for the UK and France being 56% and 14% respectively.

While the use of SVARs allows us to explore the differences in food inflation dynamics across EU Member States, it does not permit us to explore the reasons for these differences. This relates to the second objective of this paper: using estimates from the variance decompositions we correlate the importance of commodity shocks in retail prices with proxy measures of key characteristics of the retail food sectors in the Member States we cover. We find relatively strong correlation between the role of world wheat prices in retail bread inflation and barriers to competition in the retail sector, the pervasiveness of private labels in these countries (which proxies for vertical control) and the share of bread and cereals in total food expenditure. These dimensions of the food sector across the EU appear to be better correlated with the differences in the food inflation experience compared with macroeconomic (i.e. membership of the Eurozone) or openness to world markets. We also investigate the role of discounters (as suggested by Burkovite *et al.*, (2009) and ECB (2011)) but do not find evidence of a link with the food inflationary experience. While acknowledging the caveat that the number of data points in the correlations is low, they are nevertheless indicative of the importance of the structure of markets in explaining pass-through and confirm concerns emanating from policy circles across the EU.

The paper is organised as follows. In Section 2, we document the experience of food price inflation generally for the EU and highlight the contrasting experience in retail bread inflation which is the basis for the empirical evaluation across the 11 Member States we cover in the remainder of the paper. In Section 3, we review briefly the related literature that relates to the pass-through of world commodity shocks to domestic prices. The econometric framework we employ is detailed in Section 4 and, in Section 5, we report the main results that arise from the estimated VARs. We consider the factors that may give rise to the differences in the dynamics of food price inflation across the EU by correlating the results from the variance decompositions with country-level differences with alternative measures associated with the food supply sectors across our sample countries. In Section 6, we summarise and conclude.

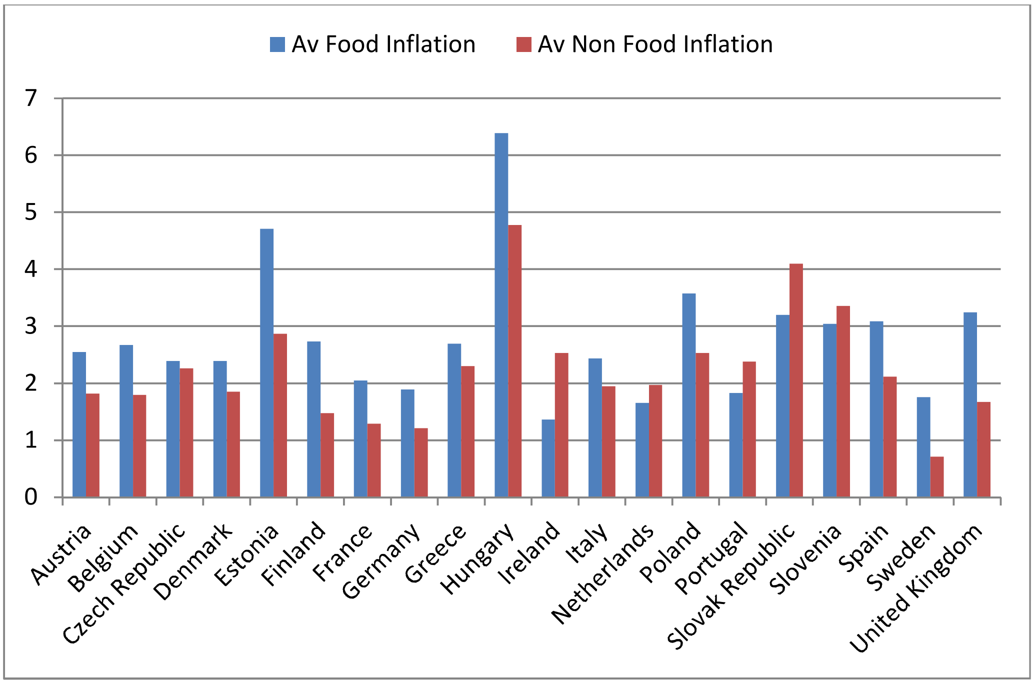
2. Experience of Food Inflation Across the EU

There are three principal observations to make about the experience of food price inflation across the EU: (i) the average rates of food inflation varies considerably across EU Member States; (ii) average rates of food inflation, exceed non-food inflation for most, but not all, EU Member States; (iii) there are considerable differences in the experience with regard to the variability of food inflation.

Take first of all, the experience of food and non-food inflation: this has varied considerably across EU Member States as shown in Figure 1. The experience ranges from a relatively high level of annual average food inflation in Hungary (at 6.4 per cent) and Estonia (4.7 per cent) to a relative low level of average food inflation for Ireland, the Netherlands, Sweden and Germany, all of which experienced annual average food inflation of between 1-2 per cent over the 2000-2013 period. The UK also stands out as having experienced high levels (in excess of 3%) of food inflation.

The figure also reveals that in most EU Member States, food inflation has exceeded non-food inflation. These differences are particularly notable for Sweden, the UK, Estonia and Finland, where food inflation has on average been twice that of non-food inflation over the period. In contrast, in Ireland, the Netherlands, Portugal, the Slovak Republic and Slovenia, non-food inflation has exceeded food inflation.

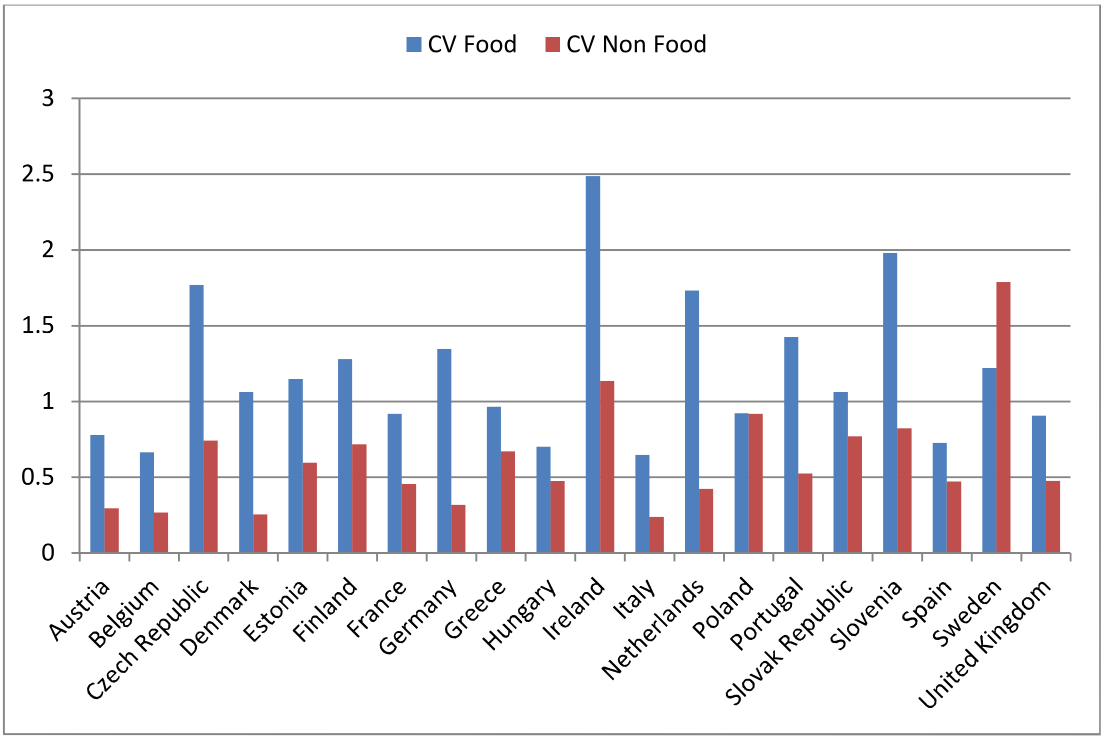
Figure 1: Annual Average Rates of Food and Non-Food Inflation across EU Member States, 2000-2013



Source: OECD

The potential concerns of high food inflation is compounded by its variability; despite the impact of food inflation on the cost of living, the high variability of food inflation makes it more difficult for monetary authorities to address without the risk of exacerbating output variability. The issues associated with targeting food inflation (despite the high levels that have been witnessed in recent years) has been summarised in IMF (2011) and Walsh (2011) with issues associated with persistence or second round effects being addressed by Cechetti (2009). The variability of food inflation across the EU is highlighted in Figure 2 which also presents evidence on the variability of non-food inflation by way of comparison. For the most part, the variability of food inflation compared with non-food inflation is more significant than the comparison with the average levels of food inflation presented in Figure 1; only in Sweden is the variability of non-food inflation higher than food inflation.

Figure 2: Coefficient of Variation of Food and Non-Food Inflation across EU Member States, 2000-2013



Source: OECD

In sum, the experience of food inflation across EU Member States varies considerably, in terms of levels (these differences being more exacerbated during the recent world commodity price spikes), in relation to differences with non-food inflation and in its variability. While the degree of these differences are more notable when comparing Euro area with non-Euro, even within the Euro area, there are still notable differences in the experience of food price inflation.

In the econometric models of food inflation below, we focus on 11 EU Member States and on a specific commodity-retail food chain i.e. wheat-retail bread; the selection of countries was based on accessing the relevant data that we could apply the framework consistently across countries. With regard to the differences in retail bread inflation across the 11 Member States, while exhibiting some common features associated with the peaks in inflation that coincided with the commodity price spikes in 2007-2008 and 2011, there are nevertheless important differences. These relate to the average levels and the variability in bread inflation over the sample period and the cumulative changes in the bread price index between 1997 and 2013. In Figure 3, we present the data for four Member States (Italy, France, the UK and Portugal) that highlight these differences. Aside from noting that the axes differ for each country, the pattern of inflation varied considerably with more variable inflation prior to the first spike in 2007 for France and Portugal and, again for these two countries, evidence of deflation.

Figure 3: Comparative Experience of Retail Bread Inflation in EU Member States, 1997-2013.

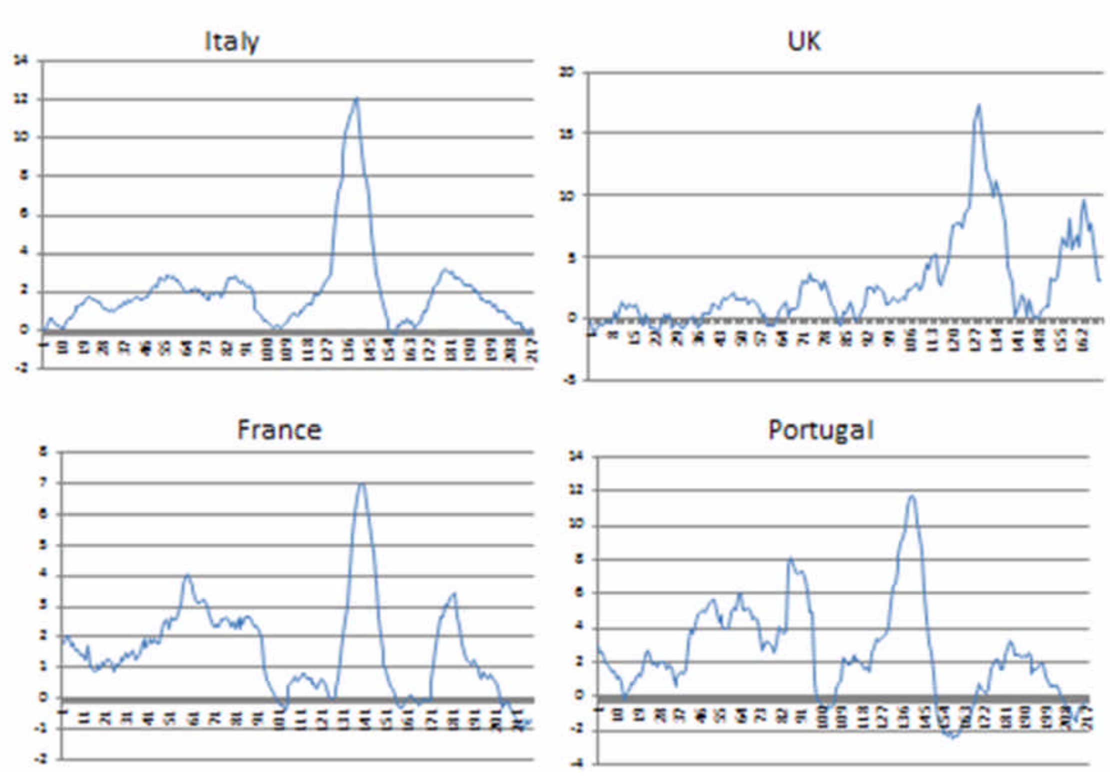


Table 1 reports the cumulative percentage increase in retail bread prices across the 11 Member States. Though month-on-month changes in retail bread prices indicate some degree of volatility, on average between the start of 1997 through to the end of 2014, retail bread prices had risen by 40 per cent across the 11 countries. But there have been noticeably different experiences with lower increases in France and the Netherlands (26 and 28 per cent respectively) and, at the higher end, Belgium (54 per cent), Denmark (49 per cent) and Austria (49 per cent).

Table 1: Cumulative Percentage Increases in Retail Bread Price Index for 11 EU Member States: January 1997-December 2014

Country	Cumulative Percentage Increase in Retail Bread Price Index
Austria	48
Belgium	54
Denmark	49
France	26
Germany	30
Italy	38
Netherlands	28
Portugal	43
Spain	46
Sweden	32
UK	43
Average	40

3. Related Literature

Research on the links between world commodity prices and inflation has largely focussed on oil prices. Summaries of this research can be found in Hamilton (2008), Kilian (2008a) and World Bank (2015). With more direct reference to the EU experience, Peersman and Van Robays (2009) note that the links between oil prices and inflation varies considerably across the EU with one of the reasons for the different experience being due to the existence of second round effects of oil prices on wage bargaining. With regard to the impact of world agricultural prices, while there has been extensive commentary on the causes of the recent price spikes that were experienced on world markets in 2007-2008 and 2011, the inflationary consequences has received comparatively less attention. IMF (2011), Walsh (2011) and Gelos and Ustyugova (2012) have estimated Phillips curve-type relations across a number of countries and have highlighted the differences in the links between domestic retail and world prices between developed and developing countries[2].

Central to assessing the links between world commodity prices and domestic inflation is the pass-through effect. Since most countries produce commodities that are directly substitutable with commodities imported from world markets and typically have policies that apply to the domestic agricultural sector, there is both a horizontal and vertical dimension to the pass-through effect. As Ferrucci *et al* (2012) have noted, the existence of the EU's Common Agricultural Policy is important in gauging the strength of the linkage between world and domestic prices in the EU where domestic support prices breaks the horizontal link between world and domestic agricultural prices. To a large extent, this issue has been ameliorated in recent years given the changes in agricultural support policies in the EU with agricultural prices exhibiting behaviour broadly comparable to that witnessed on world markets[3].

As noted above, policy concerns within the EU and recent research has pointed to the differences in the structure and extent of competition in the food sector across EU Member States to account for the differences in food inflation. This is premised against the background of high (and rising) levels of concentration in the food sector, differences in the penetration of private labels and the role of low-price discounters that have been observed across the EU. These characteristics of the food sector tie with the issue of vertical price transmission and relates to a long established literature on how dimensions of competition in the food sector can have an impact on the price transmission process. As outlined by McCorriston *et al.* (1999), there are essentially two main factors that determine price transmission. First, is the share of agricultural inputs in the industry cost function: reflecting the declining share of agricultural inputs in the value of retail food products, even in the absence of concerns about competition in the food sector, the price transmission effect should be bounded at this level. This also implies that-given the relatively small share of agricultural inputs in the value added of the processed food product sold at retail, other cost factors will also affect retail food prices. Second, in the presence of concerns about competition in the food sector, McCorriston *et al*. (*ibid*) show that the effect depends on the elasticity in the food industry mark-up. This concept parallels related insights into price transmission including Klenow and Bils' reference to a 'super-elasticity' (Klenow and Bils, 2011). Assuming the demand function is not 'too' convex, the main insight here is that in the presence of a positive price shock to agricultural inputs originating from world markets, the industry mark-up will fall and serve to dampen the final effect on retail food prices. Empirical research on the food inflation aspects following world price shocks (though mostly confined to the

[2] One of the reasons oil prices may differ from food price effects in the context of monetary authorities dealing with the potential inflationary consequences is the absence of persistent effects due to food price inflation. See also Cecchetti (2009) on this.
[3] In other countries, this is an important issue as the use of trade barriers and other domestic instruments severs the link between price behaviour on world and domestic markets.

US) has largely confirmed the final retail price effects will be less than the price changes arising on world markets (see Berck *et al.* (2009) and Leiptag (2009)) with Nakamura and Zerom (2010) being the most detailed analysis of this issue; they confirm the role of competition in the intermediate stages of the food sector via the mark-up elasticity effect.

However, other dimensions of competition in the food sector may also matter. Hamilton (2009) shows that in the context of multi-product food retailers, there are two influences that may influence the effect on prices. First, there is the cost effect which relates to the standard price transmission process; but second, multi-product retailers may respond to cost increases by reducing the number of products available. This anti-competitive effect reduces competition and increases prices. Hamilton and Richards (2011) confirm these two effects: using data for the US ready-to-eat cereals markets, when the price transmission effect is isolated from the variety-reducing effect, price transmission is less than perfect; when the variety effect is accounted for, retail prices rise by more than the change in costs.

The increased penetration of private labels is an additional feature of food retailing across the EU. While this acts to distinguish retail chains, it also has a vertical effect in that it gives retail chains more vertical control and therefore can also affect price transmission by diminishing the double marginalisation effect. This is confirmed by Li and Hong (2013) who show-both theoretically and empirically- that the increased penetration of private labels will increase price transmission in the face of commodity price shocks.

In sum, although competition in the food sector is complex, the (limited) theoretical research on this issue confirms that dimensions of competition in the food sector could have an important bearing on the price transmission process and hence the inflationary consequences arising from events on world markets. This literature ties with the recent concerns regarding the difference experiences in food inflation across the EU as being related to differences in the structure and the intensity of competition in the food sector across EU Member States (see Burkovite *et al.*, (2009) and ECB (2011, 2014). We return to these issues below when we have considered the extent to which the impact of world prices varies across EU Member States.

4. Empirical Analysis

4.1 Determinants of Food Inflation

Most recent studies of the pass-through of world agricultural prices to retail food prices specify a bivariate model and ignore other factors that may have a bearing on retail prices (see, for example, Berck *et al*. (2009) and Gelos and Ustyugova (2012)). In the framework outlined below, we specify a structural VAR that accounts for a wider range of factors including not only world agricultural prices (valued in US dollars) and retail food prices but also exchange rates, oil prices and unemployment. Exchange rates matter, particularly when comparing the food inflation experience across the EU, as movements in national currencies or the Euro can offset or exacerbate the equivalent dollar price of commodities imported from world markets. World oil prices can also have a potential effect on retail food prices. There are two potential channels for this: first, oil prices can affect world agricultural prices through raising the costs of fertiliser and by increasing the profitability of biofuels which –as has been documented in relation to the causes of the world commodity price spikes-diverts land away from food production; second, since agricultural prices are not the only cost in the production and distribution of food products, oil prices can proxy for the cost of other factors in the food industry cost function. Preferably, labour costs would have been included in the model as these would have accounted for other costs in the food industry cost function; however, these data were not available at monthly frequency. We also include monthly unemployment as a determining variable: this variable acts as a demand shifter in the model to reflect macroeconomic conditions. Employing a structural VAR allows us to be more detailed with regard to the contemporaneous relationship among the five variables in the model.

In the initial specifications, we explicitly allowed for domestic agricultural prices to play a role hence capturing both the horizontal and vertical dimensions of pass-through from world agricultural prices noted above. However, this variable did not offer any additional insights into the pass-through process, in most cases, the time series patterns of producer prices being the same as world agricultural prices and was therefore excluded from the final model specification.

In sum, we specified a 5 variable structural vector autoregression model with the variables for each country being world agricultural prices, domestic retail prices, the exchange rate (Euro or national currency vis-à-vis the US dollar), world oil prices and national unemployment. Using 194 monthly observations covering the period 1997 (November) to 2013 (December) a structural VAR model is estimated for this commodity chain for 11 separate countries: Austria, Belgium, Denmark, Germany, France, Italy, the Netherlands, Portugal, Spain, Sweden and the UK.[4] Methods and results now follow.

4.2 Econometric Methods

The data series underpinning the inflationary process are typically non-stationary and to accommodate this, we employ a cointegrated vector autoregressive model (C-VAR) which offers a tractable framework for the empirical modelling of food inflation. Since the mechanics of the C-VAR are well known (see *inter alia* Johansen (1988), Juselius (2006)), we highlight a few features that are germane

[4] The retail prices of bread and unemployment figures in each country are published by Eurostat. The world price of wheat and oil (UK Brent, light blend) are published in IMF Primary Commodity Prices. Exchange rate data are sourced from IMF Financial Statistics. Further details are available upon request.

to the current application. To aid estimation and interpretation, it is common to express the C-VAR in its error correction form given by:

$$\Delta \mathbf{x}_{\mathrm{t}} = \boldsymbol{\alpha}\boldsymbol{\beta}' \mathbf{x}_{\mathrm{t}-1} + \boldsymbol{\Gamma}_i \Delta \mathbf{x}_{\mathrm{t}-1} + \cdots + \boldsymbol{\Gamma}_{k-1} \Delta \mathbf{x}_{\mathrm{t}-k+1} + \boldsymbol{\Phi}\mathbf{D}_t + \boldsymbol{\varepsilon}_{\mathrm{t}} \qquad (1)$$

in which $\mathbf{x}_t$ is a $(p \times 1)$ vector of non-stationary variables, Δ is the difference operator such that $\Delta \mathbf{x}_t = (\mathbf{x}_t - \mathbf{x}_{t-1})$, $\mathbf{D}_t$ is a matrix of deterministic terms and $\boldsymbol{\varepsilon}_t$ is a vector of disturbances in which each series of errors is assumed to be serially independent with zero mean and finite variance $\boldsymbol{\varepsilon}_t \sim NI_p(\mathbf{0}, \boldsymbol{\Omega})$. While similar in structure to the stationary VAR that is commonly used to investigate commodity shock pass-through (see, for example, Porqueddu and Venditti (2012), Ferrucci *et al*. (2012)), the Vector Error Correction Model (VECM) explicitly incorporates long-run (cointegration) linkages among the data in the $\boldsymbol{\alpha}\boldsymbol{\beta}' \mathbf{x}_{\mathrm{t}-1}$ term, thereby improving the estimate of pass-through in both the short and long run, although in the absence of cointegration, $\boldsymbol{\alpha}\boldsymbol{\beta}' = 0$ and the VECM collapses to the orthodox stationary VAR.

To benefit from the VECM, the variables that form the equilibrium price transmission relationship must be included in $\mathbf{x}_t$. In light of the discussion in the previous section, wheat prices are unlikely to be the sole determinant of retail bread prices.[5] In addition to the domestic retail price of bread (b_t) and the dollar-denominated price of wheat on international commodity markets (w_t), $\mathbf{x}_t$ includes factors that are likely to play key roles in the price transmission process in each country, namely the dollar exchange rate (e_t) and shifters in the supply and demand schedules which we proxy by the dollar denominated price of oil (o_t) and domestic unemployment (u_t) respectively.

In equation, (1), parameters of $\boldsymbol{\alpha}$ load deviations from equilibrium (*i.e.* $\boldsymbol{\beta}' \mathbf{x}_{t-1}$) into $\Delta \mathbf{x}_t$ for correction, quantifying the average speed at which each variable adjusts to maintain equilibrium. Coefficients in $\boldsymbol{\Gamma}_i$ estimate the short-run *ceteris paribus* effect of shocks to the variables on $\Delta \mathbf{x}_t$, allowing the short and long-run responses to differ. In the empirical analysis, the Schwarz Information Criterion is used to determine the lag length (k); Trace and Maximal Eigenvalue cointegration test statistics are used to assess the existence of the price transmission relationship.

Given interest in the dynamics of commodity pass-through, it is common to use impulse response analysis to provide dynamic simulation of the effect of a common commodity shock of identical size and duration on the domestic price of bread. Since (1) is a reduced form, $\boldsymbol{\varepsilon}_t = [\varepsilon_{1t} \cdots \varepsilon_{pt}]$ is likely to comprise elements that are contemporaneously correlated in which case the covariance matrix:

[5] Cointegration testing conducted on wheat and bread prices alone could not find any evidence of an equilibrium relation in the countries investigated at conventional levels of significance.

$$\mathbf{\Omega} = \begin{bmatrix} \omega_{1,1} & \cdots & \omega_{1,p} \\ \vdots & \ddots & \vdots \\ \omega_{p,1} & \cdots & \omega_{p,p} \end{bmatrix}$$

is non-diagonal. In this set-up, simulating shocks in a particular element of $\boldsymbol{\varepsilon}_t$ keeping other errors constant will violate this correlation structure, misrepresenting the dynamic relationships being investigated. To obtain the orthogonal innovations required for valid impulse response analysis, we assume there exists a structural economic representation of (1) given by:

$$\mathbf{A}\Delta\mathbf{x}_t = \widetilde{\boldsymbol{\alpha}}\boldsymbol{\beta}'\mathbf{x}_{t-1} + \sum_{i=1}^{p-1} \tilde{\boldsymbol{\Gamma}}_i \Delta\mathbf{x}_{t-i} + \widetilde{\boldsymbol{\Psi}}\boldsymbol{w}_t + \boldsymbol{\nu}_t \tag{2}$$

where $\mathbf{A}$ represents a $(p \times p)$ matrix of coefficients defining the contemporaneous linkages between variables in the system, $\widetilde{\boldsymbol{\alpha}} = \mathbf{A}\boldsymbol{\alpha}$, $\tilde{\boldsymbol{\Gamma}}_i = \mathbf{A}\boldsymbol{\Gamma}_i$, $\widetilde{\boldsymbol{\Psi}} = \mathbf{A}\boldsymbol{\Psi}$ and

$$\boldsymbol{\nu}_t = \mathbf{A}\boldsymbol{\varepsilon}_t$$

are the structural shocks, which as pure disturbances, are assumed to be serially uncorrelated and uncorrelated with each other with zero mean with diagonal variance–covariance matrix $\boldsymbol{\Sigma} = \mathrm{E}[\boldsymbol{\nu}_t\boldsymbol{\nu}_t{}']$. Obtaining orthogonal innovations from the $\boldsymbol{\varepsilon}_t$ in (1) can be achieved by imposing any set of at least $(p^2 - p)/2$ restrictions on (2). This is commonly achieved by Choleski decomposition (see Lutkepohl 2006, p.658) which requires that $\mathbf{A}$ is lower triangular with unit diagonal:

$$\mathbf{A} = \begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ a_{p,1} & \cdots & 1 \end{bmatrix}$$

so that $\boldsymbol{\Sigma} = \mathbf{A}\boldsymbol{\Omega}\mathbf{A}'$ has uncorrelated errors by construction. While all orthogonalisaiton schemes are to some extent conjectural, the causal ordering of contemporaneous relationships embodied by $\mathbf{A}$ is often inappropriate (see Kilian, 2012). Commodity price pass-through represents something of an exception. Given the nature of the food chain for staples such as bread, in which internationally-determined raw material costs drive domestic variables contemporaneously but not *vice versa,* the recursive structure of $\mathbf{A}$ is a plausible characterisation (see Ferrucci *et al.,* 2012). More specifically, we stipulate $\mathbf{x}_\mathrm{t} = (e_t, o_t, w_t, u_t, b_t)'$ so that shocks to the exchange rate which, being first in the ordering, are exogenous to the food chain. This primacy of the exchange rate reflects that both oil and wheat are priced in dollars and so are likely to embody not only market forces but exchange rate effects contemporaneously. Oil is positioned next in the chain. As the largest single commodity traded and a key agricultural input, the price of oil is expected to be contemporaneously causal to the price of wheat. Further along the chain is domestic demand, measured here by unemployment levels (u_t) and finally the retail price of bread (b_t) which by construction is free to respond to both international and domestic influences. Note here that being more contract-based, it is unlikely that domestic labour markets and retail prices are sufficiently responsive to react contemporaneously to influences on international markets, although they are allowed to do so.

When considering the validity of such an identification scheme, it is important to recognise that the ordering embodied in $\mathbf{A}$ applies to contemporaneous interactions only; feedback effects among the variables are unrestricted and thus may be estimated freely from the data. Given the monthly frequency of observation, lagged feedback may be sufficient to capture dynamic interactions among these data, so that violation of the orthogonality scheme embodied in $\mathbf{A}$ is likely to be confined to relationships among the international variables since adjustment to a common third variable cannot be ruled out. Given our focus on the transmission of shocks from world markets into retail bread prices, we gauge the sensitivity of commodity price pass-through by simply rotating the positions of the international variables in $\mathbf{x}_t$.

With the orthogonal innovations ν_t the impulse response function can be derived (see Lütkepohl (2006), pp.57-59) to deliver the dynamic responses that include not only the lagged feedbacks but also the contemporaneous interactions embodied in the estimated system (2). While our interest is primarily in the domestic effect of a commodity price shock on domestic price of bread across the sample of countries, it is also possible to use ν_t to estimate the effects of all the variables, both domestic and international, on bread prices and by logical extension calculate the contribution of each variable to evolution of bread prices over time using the forecast error variance decomposition (see Lütkepohl (2006), pp.63-64). Results of course reflect the choice of variables in $\mathbf{x}_t$ and restrictions embodied in $\mathbf{A}$ but mindful of these caveats results of the empirical cross country investigation are presented in the following sections.

4.3 Model Selection

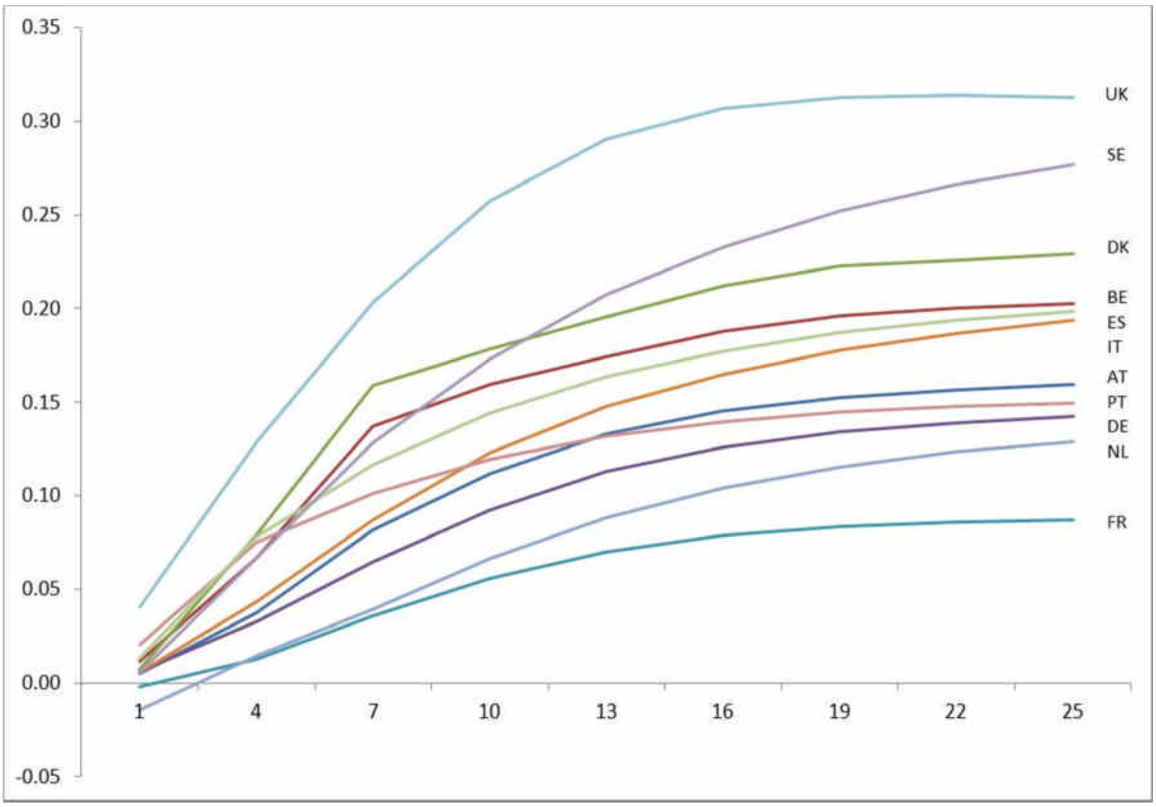
As a precursor to the main analysis, all variables are tested for non-stationarity, this being a necessary condition for cointegration. Results (see Appendix Table 1) confirm the non-stationarity of the data allowing unrestricted VECM models to be formed for each country comprising the international variables (US dollar exchange rate, dollar denominated prices of oil and wheat) and domestic variables (unemployment levels, and the retail price of bread) all expressed in natural logarithms, so that $\mathbf{x}_t = (e_t, o_t, w_t, u_t, b_t)'$ and $\mathbf{D}_t = (c, s_i)'$ incorporates an unrestricted constant and centred seasonal dummies. To reflect differences in the functioning of the food chain across the 11 Member States, the variables contained $\mathbf{x}_t$ and $\mathbf{D}_t$ and the lag length (k) is determined empirically by Shwartz Information criterion for $k = 1, \ldots, 11$. In most countries, low-order VARs deliver the best explanatory power, with the optimal lag typically being 3 or 4 months.

Cointegration tests (see Appendix Table 2) offer strong evidence for the existence of a single long run relationship among the variables at the optimal lag length in each country. Of the 22 tests conducted evaluating the null of no cointegration, 21 reject in favour of at least one cointegrating relationship at the 5% level. All remaining *p*-values are larger than 0.05 indicating that there is no evidence of more than one relationship in any of the countries at the 5% level. Taken together, the evidence firmly points to a single relationship among the data in all countries.

4.4 Commodity Price Transmission

We gauge the effects of a common world wheat price shock on domestic retail bread prices across individual Member States through the use of impulse response functions, which are displayed in Figure 4. As is clear from the figure, some similarities are evident, in that dynamic responses are inelastic, detected in all countries and tend to rise at a declining rate so that, in large part, adjustment within in any country takes occurs within 18 months. Despite these similarities, it is the cross-country variation in the magnitude of price transmission that is the most striking feature, with the UK exhibiting a long run response three times that of France. To help illustrate these differences, Figure 5 reproduces the impulse response functions evaluated at just two periods, 6 and 24 months after the shock corresponding to short and long run responses respectively.

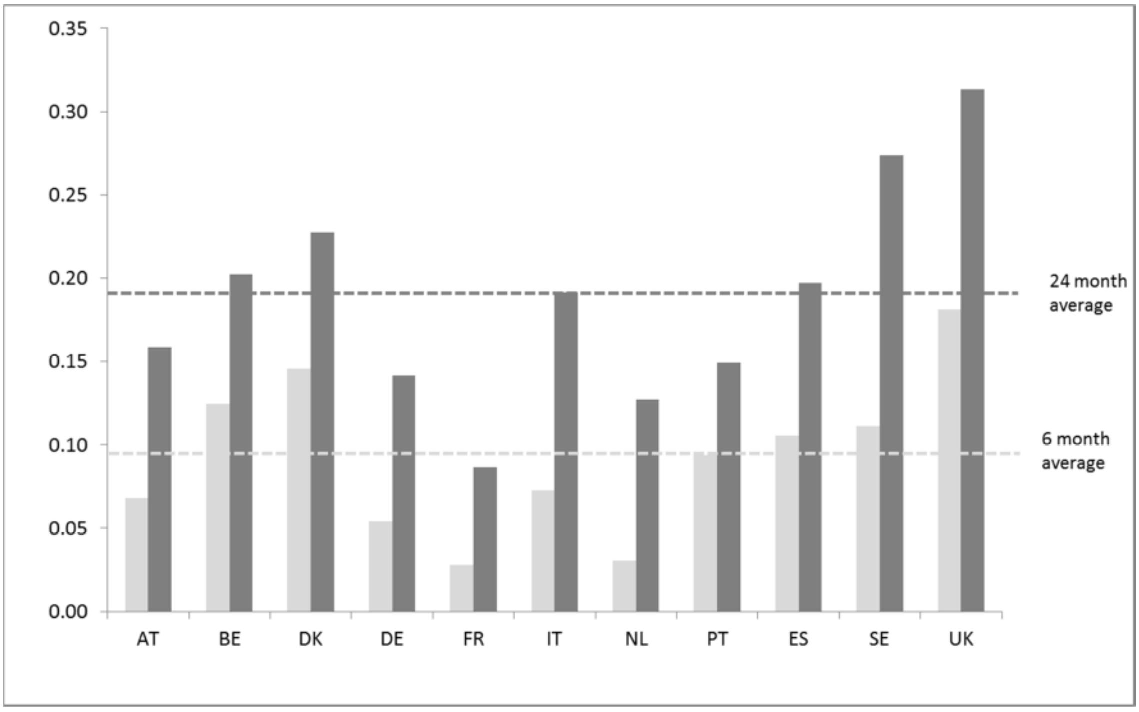
Figure 4: Impulse Response Functions of Bread Prices to a one percent shock in World Price of Wheat.



Referring to Figure 5, the average long-run response to a one percent shock is estimated at 0.19, around twice the short run response of 0.09. Countries that are below (above) the average response in the short run are also below (above) the average in the long run too, although the ratio of long-to-short run response varies by country; the long-run response being over three times the short-run effect in the Netherlands yet under a half in Denmark, Portugal and Belgium. Interestingly, a Euro-zone effect is apparent, with UK, Sweden and Denmark exhibiting noticeably larger responses (at both 6 and 24 months) than the other countries all of which operate the Euro. Even among the Eurozone countries there marked differences in the magnitude of price transmission with the low values of France, Germany and the Netherlands contrasting with that of Belgium and Spain.

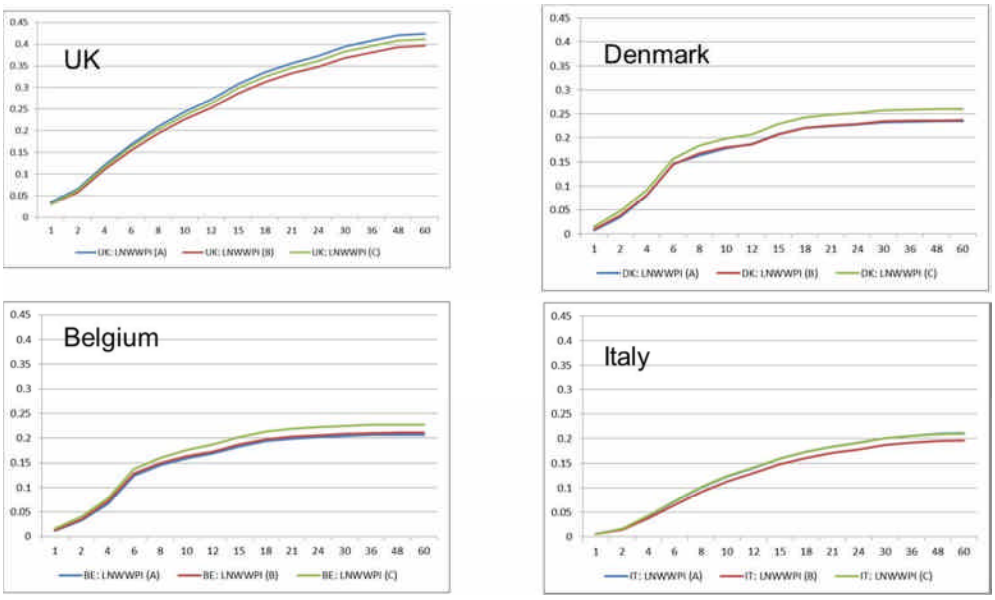
In the previous section it was noted that the results of the impulse response functions are conditional upon the identification scheme that is adopted. Since the issue of ordering is most relevant for the ordering of the international variables this is where our attention is focussed. Specifically, we consider the impulse response function of bread prices with respect to the dollar price of wheat in three identification schemes: 'A' where wheat lies at the top of the chain, 'B' where is it sandwiched between exchange rates and oil and 'C' where it is at the base of the chain. Figure 6 presents results for the impulse response function of bread prices under these three orderings for four countries that encompass the largest and smallest differences among all the countries in our sample. As is clear, any differences between the ordering is relatively modest, indicating that for the purposes of commodity price pass-through results are largely robust to the identification scheme that is adopted.

Figure 5: The Estimated Response of Domestic Bread Prices to a One Percent Shock in World Wheat Prices in the Short and Long Run



The central message from the impulse response analysis is that the pass-through of shocks do indeed differ in each country and in several cases substantially so, implying that common shocks should not be expected to yield that same response - even for a common product such as bread. While this is a key and important result, it does not shed light on which of the shocks have been the most important in driving bread prices over the sample period, since even if the response to a factor is identical in two countries, (i.e. the response to an impulse is the same), the contribution of this factor in retail bread prices may differ. To address the relative importance of each of the variables in each country to bread prices, we perform a forecast error variance decomposition of the C-VAR, which is detailed below.

Figure 6: Impulse Response Effects with Alternative Orderings of the International Variables



4.5 A Variance Decomposition of Bread Prices

The relative importance of each variable in explaining the variation in bread prices has two components: the response of bread prices to a shock of known size (i.e. the impulse response) and the amount a variable changes (i.e. the size of the shock). Combining these two effects is what the forecast error variance decomposition does. Table 2 summarises the results of a forecast error variance decomposition of bread prices across countries. As is clear from the results, there are two important sources of bread price variation: the world wheat market and the domestic food chain. Combined, they typically account for around 85% of the variation in bread prices. Of the two, shocks that originate in the retail sector (which represents the effect of labour costs, technological adoption, productivity improvements and retail margins) are the most important. As an average across all countries they account for half of the variation in bread prices, the contribution being the lowest in the UK at around one-quarter and highest in Austria and Germany where it is closer to two-thirds. The second major influence on the price of bread is the price of wheat. Results suggest that changes to the dollar price of wheat on the world wheat markets accounts for 36% of the variation in bread prices on average across countries, the UK and Sweden recording the highest contribution at 65% and 56% respectively.

Oil prices, exchange rates and unemployment play relatively minor roles in bread prices in virtually all the countries. While differences across Member States do exist, cases where one of the variables accounts for more than 10% of bread price variation is rare, particularly so for exchange rates and unemployment, the average individual contribution of unemployment (exchange rates) to retail bread prices being around 4% (2%) respectively.

Table 2: The Relative Contribution of Shocks to Bread Prices across EU Member States

	Source of the Shock				
	World wheat market	World oil market	Exchange rate	Domestic unemployment	Domestic food chain
Austria	19.48	0.81	0.86	16.73	62.12
Belgium	39.29	6.10	3.06	0.02	51.54
Denmark	31.25	8.16	1.67	6.63	52.28
Germany	35.69	2.28	0.43	0.85	60.74
France	18.79	21.42	1.36	1.01	57.43
Italy	42.46	7.98	0.26	7.92	41.37
Netherlands	23.97	22.57	0.69	1.85	50.92
Portugal	22.25	7.75	9.99	5.42	54.59
Spain	40.14	4.71	-	1.21	53.94
Sweden	56.18	0.41	1.77	4.25	37.39
United Kingdom	65.34	8.66	0.85	0.41	24.74
Average	**35.90**	**8.26**	**2.09**	**4.21**	**49.73**

5. Accounting for the Differences in Food Inflation across EU Member States

What factors contribute to the different experience of food inflation across EU Member States? The data presented in Section 2 points to the fact that Euro area countries have (on average) lower rates of, but more variable, food inflation (see Figures 1 and 2). In relation to retail bread inflation, the behaviour of retail prices has differed and the cumulative effects of retail bread price changes has led to substantial variation across EU member States (see Figure 3 and Table 1 respectively). From the impulse response outcomes in Section 4, Euro area countries are less prone to shocks from world wheat markets (see Figures 3 and 4) and the contribution of world wheat prices to food inflation lower (Table 2). While openness to world markets is one possible factor in explaining the differences in food inflation across the EU, as discussed above, recent attention has turned to the characteristics of the food sector across EU Member States, though the factors mentioned to date have been more suggestive without providing clear insights. We take up these issues below.

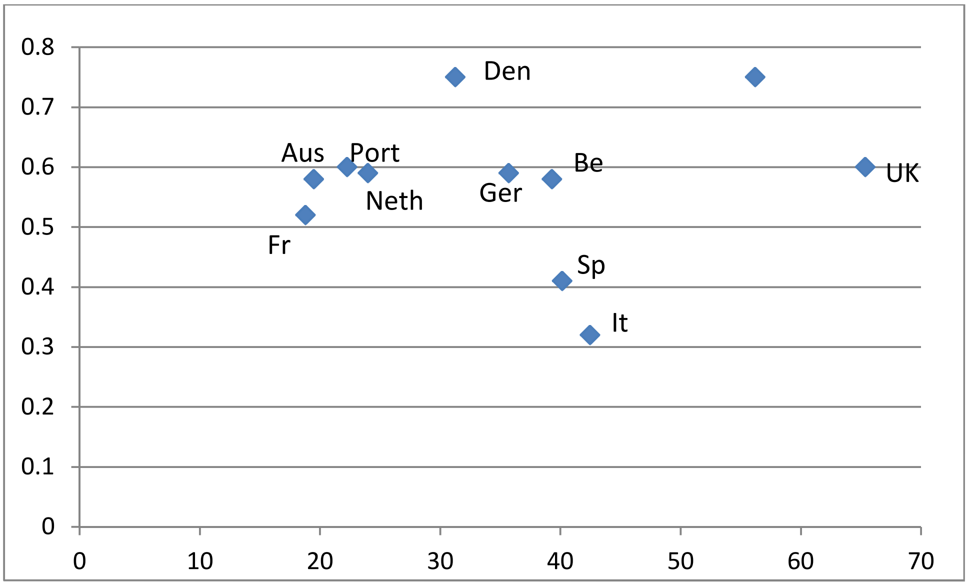
Specifically, we take the percentage contribution of the world wheat price to the variation in retail bread prices across EU Member States as reported in Table 2. We initially investigated the dependence on wheat imports and the sourcing of imports (from world markets or other EU Member States) but the correlation with the role of world wheat prices in explaining retail bread prices was low and of the wrong sign. We then considered proxies for the structural characteristics of food chains across our sample Member States as well as measures that may relate to how the food chain may function. There are two caveats to the discussion below. First, since we have only 11 Member States and employ a single measure of inflation dynamics, we are restricted to provide insights by correlating the observed characteristics of the food chain with our country-level measures of the price transmission experience. Second, competition in the food sector is complex and relates (potentially) to both market power and vertical control and where firm numbers (or measures of competition) may not give an accurate reflection of how the food chain functions.

To start, in Figure 7, we correlate food retail concentration measures with the contribution of world wheat prices to retail bread prices. Four firm concentration ratios for food retailing vary across our selected countries ranging from a relatively high level for Sweden and Denmark (equal to 75 per cent in both cases) through to 32 per cent in Italy[6]. In Figure 7, concentration ratios for food retailing in the 11 Member States are only mildly associated with the role played by world prices in determining domestic retail prices with a correlation coefficient of only 0.08.Though a starting point for thinking about the intensity of competition in a particular industry, concentration ratios are an imperfect

[6] We take these concentration ratios from Buckovite *et al*. (2009) as this gives a source of comparable data for the countries we cover.

measure of concerns about competition as while it reflects structural aspects of the food sector, it does not necessarily reflect the intensity of competition among retail chains[7].

Figure 7: Concentration in EU Retail Food Sectors and Price Transmission



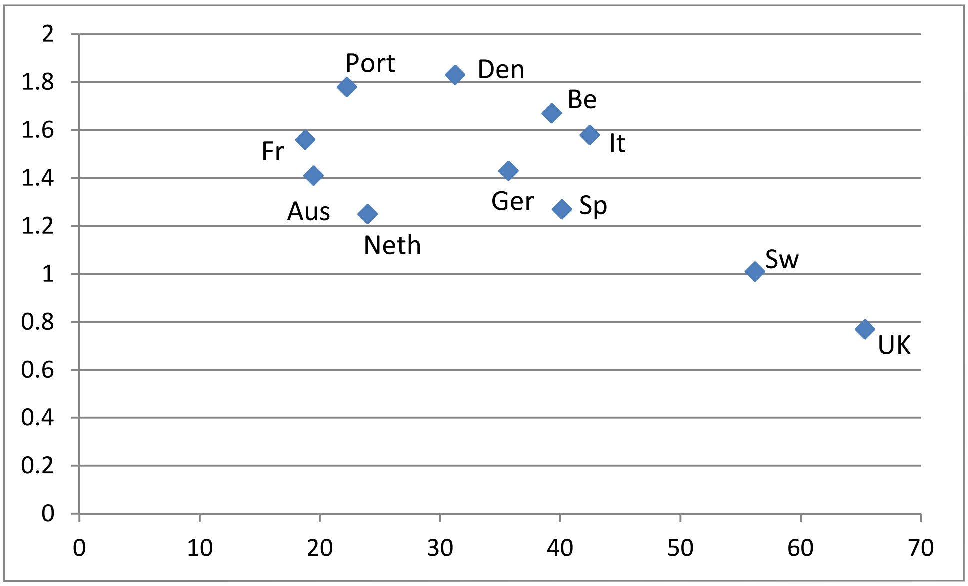
As an alternative, we use a measure of 'barriers to competition' in retail, an index measure relating to broad indicators that reflect barriers to competition across OECD member countries. The index relates to product market competition in non-manufacturing sectors and comes under the broader index coverage of barriers to entrepreneurship. Though not specifically tied to the retail food sector, it is (potentially) indicative of barriers to competition in retail sectors across the countries we cover and is produced for three separate periods (1998, 2003 and 2008); we use the index measures for 2008. The index measure for barriers to competition varies across our 11 countries ranging from a relative low value for the UK (0.77) through to high value (1.77) for Denmark. With that caveat in mind, we would nevertheless expect that if competition mattered for price transmission, this measure should be negatively correlated with the role of world wheat prices in determining retail prices. This is borne out by correlations produced in Figure 8: the lower are the barriers to entry, the greater the role of price transmission in determining retail prices with a correlation coefficient of -0.68[8].

---

[7] This was reflected in the UK Competition Commission's extensive investigation into food retailing. Despite the high levels of concentration, the assessment by the Competition Commission was that there was no abuse of market power as far as consumers were concerned.

[8] We also explored variants of this measure including the 'barriers to entrepreneurship' and 'barriers to entry'; these gave correlation coefficients in the region of -0.45. The data can be accessed at www.oecd,org/eco/pmr and an overview of the measurement of product market competition can be found in Wölfl *et al*. (2009).

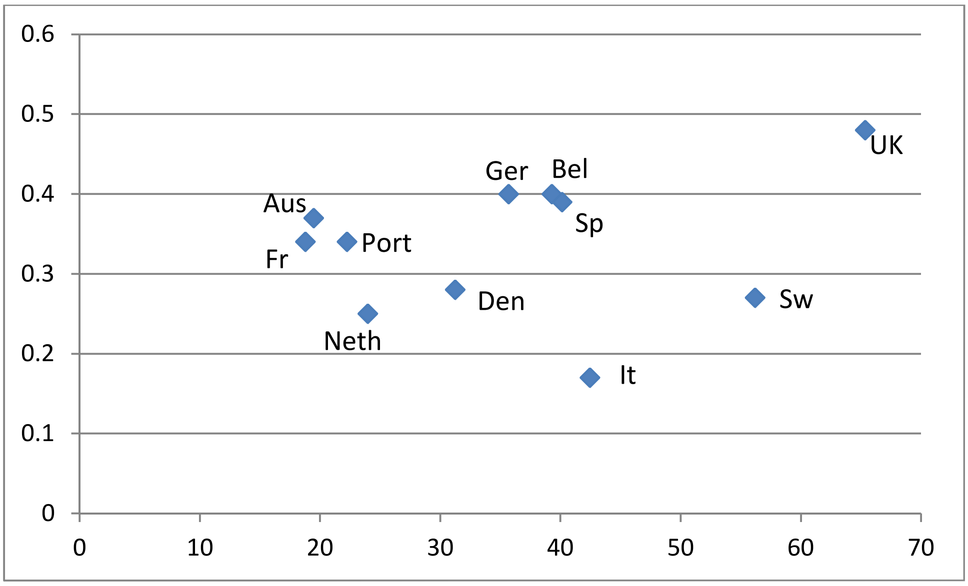
Figure 8: Barriers to Competition and Price Transmission



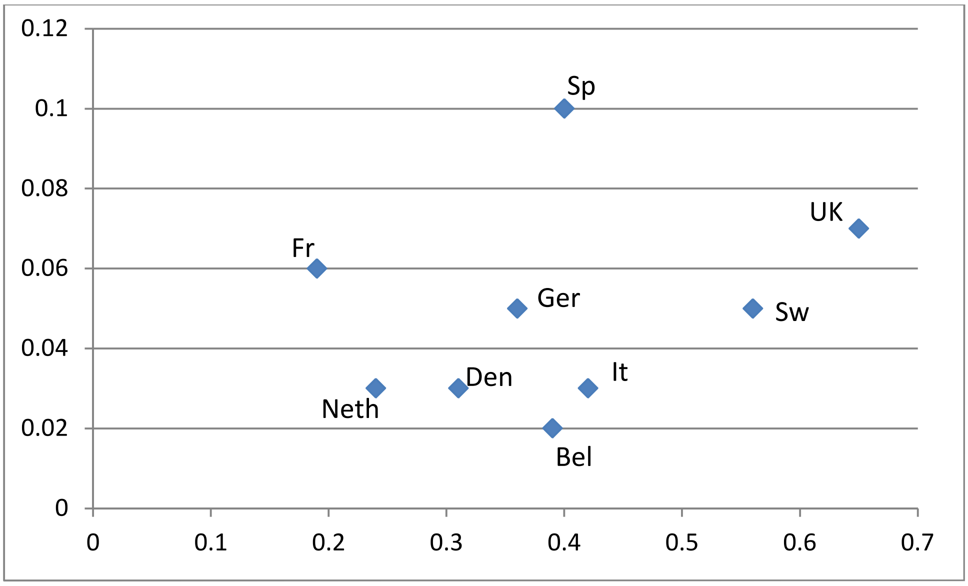
An additional feature of food retailing across the EU has been the increased penetration of private label products. The market shares of private labels ranges from a high of 48 per cent in the UK to a comparative low of less than 20 per cent in Italy. As discussed above, private labels may not only have a horizontal effect of increasing competition between branded and private labels within retail chains, but also have a vertical effect as they give retailers more control over pricing. In Figure 9, we report the correlations between private label penetration and the role of world wheat prices and retail bread prices. There are two aspects to this figure, In part (a), we show the private label shares against the role of wheat prices, the correlation being positive as expected but the size of the correlation coefficient is low (0.21). In part (b), we capture the increased penetration by looking at the change in penetration of private labels over the 2000-2007 period and the role of world wheat prices in influencing retail prices: in this case, the correlation is again positive (0.26) but stronger than looking at shares at a given point in time.

Figure 9: Private Label Penetration and Price Transmission

(i) Share of Private Label Penetration



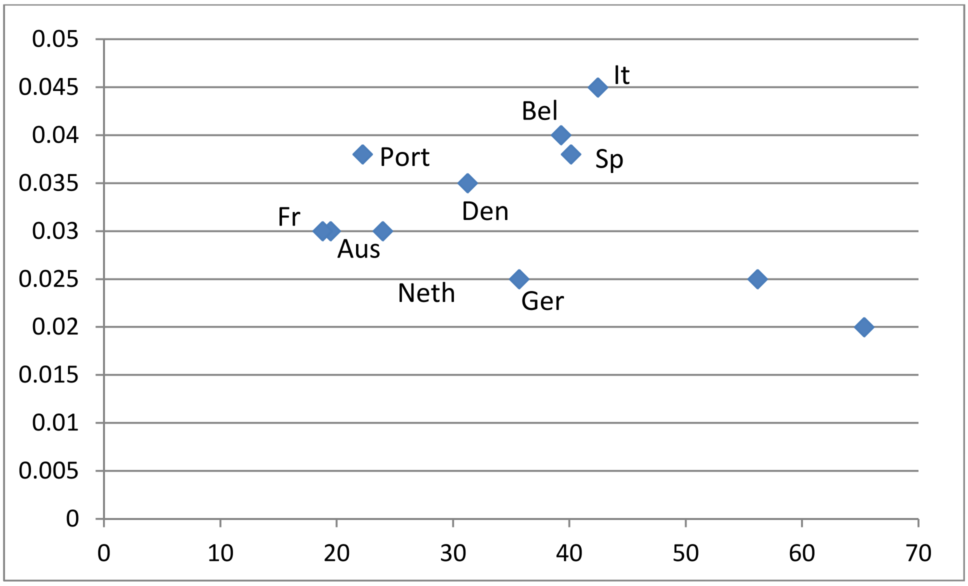
(ii) Growth in Private Label Penetration



Finally, we considered the role of 'rational inattention'. In ECB (2011), they suggest that if the product in question accounts for a relatively small share of expenditure, consumers will be less inclined to incur search costs to seek out lower prices. As such, a lower share of expenditure should be associated with a higher level of pass-through over the sample period. We investigated this by taking measures of household expenditure on bread and cereals and correlated this with the pass-through experience, the scatter of this relationship being presented in the right hand side of Figure 10.

The relationship does have the negative relationship that would be consistent with a 'rational inattention' motivation, the correlation coefficient being -0.32.

Figure 10: Proxies for Pricing Decisions and Price Transmission



The correlations presented in Figures 7-10 should, of course, be treated with (extreme) caution as they rely on a summary measure of the food inflationary process and proxy measures for competition and structural features of the food sector across EU Member States. Competition in the food sector is complex and these summary measures can only, at best, be regarded as providing limited insight into how the food sector functions. Nevertheless, the usefulness of these proxy measures is that they are available for the Member States we cover and at least give some broad indication of the differences in the food sector across the EU and which may contribute to the pass-through experience in Member States. On that basis, the correlations presented give some interesting insights into the factors that may drive the experience of price transmission and retail prices and tie with concerns expressed about the characteristics of the food retail sector across EU Member States and retail food inflation. Taken together, differences in the food chain throughout the EU do seem to matter for understanding food inflation though the measures are admittedly blunt measures for capturing the complexities of competition in food markets.

6. Summary and Conclusion

In this paper, we have explored the nature of dynamics of food inflation across EU member States. Despite a range of common policies and, for several Member States, a common currency, the experience of food inflation across the EU has varied considerably over the last decade or so. These differences are evident in terms of the average levels, the experiences associated with the recent world commodity price spikes, the difference between food and non-food inflation and the variability of food inflation. Against this background, we have explored the underlying dynamics in food inflation across the EU. Estimating structural VARs for a single and well-defined vertical chain in 11 Member States we have highlighted the differences in the impact of world price shocks on retail prices and, by employing a variance decomposition for each of the Member States, we have shown that the contribution of the factors that drive food inflation varies substantially across countries, particularly in relation to the transmission of wheat price shocks, which being international in nature, are common to all the Member States.

Recent attention has highlighted the potential differences in the food sector across the EU as one of the main reasons why the food inflation experience has been so varied. Using the contribution of world wheat prices to the behaviour of retail bread prices as a means of differentiating the experience of pass-through across EU Member States, the results confirm that differences in the functioning of the food sector matter in the pass-through process. Despite the caution associated with identifying the potential differences, the correlations are suggestive that it is certain features of the retail sector that matters which is not confined to simplistic notions of market power. Clearly, more insights on the links between the structure and functioning of the EU food sector and how they relate to the dynamics of food inflation is an avenue for future research.

References

Anand, L.J. and E.S. Prasad (2010) "Optimal Price Indices for Targeting Inflation under Incomplete Markets" NBER Working Paper No. 16290

Berck, P., E. Leiptag, A. Solis and S. Villas-Boas (2009) "Patterns of Pass-Through of Commodity Price Shocks to Retail Prices" *American Journal of Agricultural Economics*, 91: 1456-1461

Blanchard, O. J. and J. Galí (2010) "The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so Different from the 1970s?" in J. Galí and M. Gertler (eds.) *International Dimensions of Monetary Policy*, University of Chicago Press, Chicago.

Bukeviciute, L., A. Dierx and F. Ilzkovitz (2009) "The Functioning of the Food Supply Chain and Its Effect on Food Prices in the European Union" European Economy Occasional Papers 47. Brussels.

Dhyne, E., L.J. Álvarez, H. Le Bihan, G. Veronse, D. Dias, J. Hoffmann, N. Jonker, P. Lünnemann, F. Rumler and J. Vilmunen (2006) "Price Changes in the Euro Area and the United States: Some Facts from Individual Consumer Price Data" *Journal of Economic Perspectives*, 20: 171-192

ECB (2011) *Structural Features of Distributive Trades and their Impact on Prices in the Euro Area.* European Central Bank, September.

Ferrucci, G., R. Jimenez-Rodriguez and L. Onorante, (2012) 'Food Price Pass-Through in the Euro-Area: Non-Linearities and the Role of the Common Agricultural Policy', *International Journal of Central Banking*, 8(1): 179-217.

Gelos, G. and Y. Ustyugova (2012) "Inflation Responses to Commodity Price Shocks-How and Why Do Countries Differ?" IMF Working Paper, 12/225.

Hamilton, J.D. (2008) "Oil and the Macroeconomy" in S. Durlauf and L. Blume (eds). *The New Palgrave Dictionary of Economics*, 2nd edition, Palgrave, Macmillan, Basingstoke.

Hamilton, S. F. (2009) "Excise Taxes with Multi-Product Transactions" *American Economic Review*, 99: 458-471.

Johansen, S. (1988) "Statistical Analysis of Cointegrating Vectors", *Journal of Economic Dynamics and Control*, 12(213): 231-254.

Juselius, K. (2006) *The Cointegrated VAR Model: Methodology and Applications.* Advanced Texts in Econometrics, Oxford University Press: Oxford.

IMF (2011) *Global Economic Prospects Report, 2011*. International Monetary Fund, Washington.

Kilian, L. (2008a) "The Economic Effects of Energy Price Shocks" *Journal of Economic Literature*, 46: 871-909.

Kutz, L. (2008b) "A Comparison of the Effects of Exogenous Price Shocks on Output and Inflation in the G7 Countries" *Journal of the European Economic Association*: 78-121

Leiptag, E. (2009) "How Much and How Quick? Pass through of Commodity and Input Price Changes to Retail Food Prices" *American Journal of Agricultural Economics*, 91: 1462-2166

Li, N. and G.H. Hong (2013) “Market Structure and Cost Pass-Through in Retail” University of Toronto Department of Economics, Working Paper No. 470.

Lütkephl, H. (2005) *New Introduction to Multiple Time Series Analysis,* Springer-Verlag, Berlin.

Martin, W. and K. Anderson (2011) “Export Restrictions and Price Insulation During Commodity Booms” *American Journal of agricultural Economics*, 94: 422-427.

McCorriston, S., C.W. Morgan and A.J. Rayner (1998) “Processing Technology, Market Structure and Price Transmission”, *Journal of Agricultural Economics*, Vol. 49: 185-201.

Nakamura, E. and D. Zerom (2010) “Accounting for Incomplete Pass-Through” *Review of Economic Studies,* 77: 1192-1230

Peersman, G. and I. Van Robays (2009) “Oil and the Euro Area” *Economic Policy*, 603-651.

Porqueddu, M. and F. Venditti, (2012) “Do Food Commodity Prices have Asymmetric Effects on Euro-Area Inflation?” Banca D’Italia, Temi di Discussione 878.

Richards, T.J. and S.F. Hamilton (2011) “Variety and cost pass-through among supermarket retailers”

Taylor, J.B.(2000) “Low Inflation, Pass-Through and the Pricing Power of Firms” *European Economic Review*, 44: 1389-1408

Walsh, J.P. (2011) “Reconsidering the Role of Food Prices in Inflation” IMF Working Paper 11/71. IMF Washington.

Wölfl, A., I. Wanner, T. Kozluk and G. Nicoletti (2009) “Ten Years of Product Market Reform in OECD Countries-Insights from a Revised PMR Indicator” Economics Department Working Papers No. 695. OECD Paris.

Appendix: Unit Root and Cointegration Testing

The Augmented Dickey-Fuller (ADF) non-stationarity test is used to test for the presence of unit roots in the series expressed in log-levels. The appropriate lag length in the ADF regression is determined by the Shwartz Criterion for models with up to 13 lags using the 1997(1) -2011(12) sample. The ADF regression includes a constant, trend (and seasonal dummies where appropriate) and the null of non-stationarity is evaluated using the ADF test statistic at the 5% significance level (critical value of the ADF test being -3.41). All statistics are unable to reject the null, implying the series are non-stationary.

Appendix Table 1: Summary of ADF Test Results

Series	ADF Statistic	Optimal Lag	Series	ADF Statistic	Optimal Lag
Austria			Netherlands		
LnATBRPI	-2.225	4	LnNLBRPI	-1.851	3
LnATUNEM	-1.863	3	LnNLUNEM	-3.105	5
LnEUEXRT	-2.318	3	LnEUEXRT	-2.318	3
Belgium			United Kingdom		
LnBEBRPI	-2.145	3	LnUKBRPI	-1.076	3
LnBEUNEM	-1.882	3	LnUKUNEM	-2.347	5
LnEUEXRT	-2.318	3	LnUKEXRT	-2.135	3
Denmark			Portugal		
LnDKBRPI	-1.981	3	LnPTBRPI	-2.087	3
LnDKUNEM	-2.920	12	LnPTUNEM	-2.477	13
LnEUEXRT	-2.318	3	LnEUEXRT	-2.318	3
France			Spain		
LnFRBRPI	-2.994	3	LnESBRPI	-2.06	3
LnFRUNEM	-3.358	12	LnESUNEM	-2.404	8
LnEUEXRT	-2.318	3	LnEUEXRT	-2.318	3
Germany			Sweden		
LnDEBRPI	-2.106	3	LnSEBRPI	-1.935	4
LnDEUNEM	-0.865	3	LnSEUNEM	-2.689	3
LnEUEXRT	-2.318	3	LnSEEXRT	-1.623	4
Italy			World		
LnITBRPI	-2.954	4	LnWWPI	-2.831	3
LnITUNEM	-1.828	3	LnPOIL	-3.051	1
LnEUEXRT	-2.318	3			

Appendix Table 2: Cointegration Tests (p values)

(a) Trace Test

Rank (r)	Austria	Belgium	Denmark	Germany	France	Italy	Netherlands	Portugal	Spain	Sweden	UK
$r = 0$	0.020*	0.027*	0.014*	0.171	0.029*	0.017*	0.007*	0.014*	0.000*	0.006*	0.021*
$r \leq 1$	0.551	0.371	0.417	0.907	0.408	0.476	0.419	0.150	0.065	0.099	0.389
$r \leq 2$	0.567	0.537	0.739	0.812	0.651	0.867	0.761	0.213	0.217	0.801	0.654
$r \leq 3$	0.963	0.947	0.900	0.742	0.254	0.788	0.539	0.149	0.539	-	0.598
$r \leq 4$	-	-	0.767	-	-	-	0.611	-	-	-	0.759

(b) Maximal Eigenvalue Test

Rank (r)	Austria	Belgium	Denmark	Germany	France	Italy	Netherlands	Portugal	Spain	Sweden	UK
$r = 0$	0.007*	0.001*	0.007*	0.034*	0.024*	0.008*	0.002*	0.045*	0.001*	0.021*	0.015*
$r \leq 1$	0.637	0.282	0.343	0.923	0.378	0.301	0.323	0.337	0.134	0.068	0.389
$r \leq 2$	0.479	0.475	0.591	0.757	0.732	0.822	0.907	0.295	0.468	0.801	0.746
$r \leq 3$	0.963	0.670	0.863	0.742	0.254	0.788	0.480	0.149	0.539	-	0.521
$r \leq 4$	-	-	0.767	-	-	-	0.611	-	-	-	0.759

Entries in the tables are the *p* values of the test statistics evaluating the null hypothesis given in the left hand column. *p*-values less than 0.05 are starred (*) and indicate rejection of the null at the 5% significance level. Critical values are based on simulation provided by MacKinnon-Haug-Michelis (1999).