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Relative Price Dispersion and Inflation: Evidence for the UK and the US

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Abstract

One potential real effect of inflation is its influence on the dispersion of relative prices in the economy which affects economic efficiency and aggregate output. Using a novel data set for the US and UK and a VARMA asymmetric bivariate GARCH-M model of inflation and relative price dispersion, we test for the effects of inflation and inflation uncertainty on relative price dispersion. We obtain two main results: First, inflation affects relative price dispersion positively in the US supporting the menu costs model and negatively in the UK supporting the monetary search model. Second, there is no evidence for the role of inflation uncertainty in explaining relative price dispersion, either for the US or the UK.

Relative Preisunterschiede und Inflation: Evidenz für Großbritannien und die Vereinigten Staaten

Zusammenfassung

Ein potentieller realwirtschaftlicher Effekt von Inflation ist ihr Einfluss auf die Verteilung der relativen Preise in einer Volkswirtschaft. Dies beeinflusst wiederum die ökonomische Effizienz und den aggregierten Output. Der Beitrag untersucht den Effekt von Inflation und Inflationsunsicherheit auf der Grundlage eines neuen Datensatzes für die USA und Großbritannien an Hand eines „VARMA asymmetric bivariate GARCH-M“-Modells für Inflation und relative Preisunterschiede. Die Untersuchung kommt zu zwei zentralen Ergebnissen. Zum einen beeinflusst Inflation die relative Preisstreuung in den USA positiv, was das „Menu Cost“-Modell unterstützt. In Großbritannien ist dieser Effekt negativ, wodurch sich Evidenz für das „Monetary Search“-Modell ergibt. Zweitens finden sich sowohl für die USA als auch für Großbritannien keine Belege dafür, dass Inflationsunsicherheit einen Erklärungsgehalt bezüglich der relativen Preisstreuung besitzt.

Keywords: GARCH-M, Relative Price Dispersion, Inflation

JEL Classification: C32, E31

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I. Introduction

The benefits of price stability and welfare costs of inflation have been the subject of intensive research. It is widely assumed that one of the real effects of inflation is on the distribution of relative prices in the economy. Relative price dispersion (RPD) represents the variance of the rate of change in relative price levels. Menu cost models (e.g., Sheshinski and Weiss, 1977; Rotemberg, 1983) predict that inflation increases relative price dispersion, while the signal extraction models (Barro, 1976; Lucas, 1973) predict inflation uncertainty increases relative price dispersion. Monetary search models (e.g., Reinsdorf, 1994; Peterson and Shi, 2004) on the other hand predict that the effect of inflation on RPD is not obvious. Overall, the empirical evidence is mixed. Several papers find a positive relationship, but Reinsdorf (1994) finds a negative relationship, while Eden (2001) and Baharad and Eden (2004) find no link between inflation and price dispersion. Most of the studies use relatively low levels of disaggregation, with a few studies examining the issue using disaggregated data.

In this paper, we will examine the relationship between RPD, inflation and inflation uncertainty employing a highly-disaggregated price index data set. We obtain two major results: First, inflation affects RPD positively in the US supporting the menu costs model and negatively in the UK (65 sectors) supporting the monetary search model. Second, there is no evidence for the role of inflation uncertainty in explaining RPD, either for the US or the UK. We find that trend inflation is important in predicting RPD for the case of the US. While our results indicate evidence supporting the menu cost model for the US, there is little support for the signal extraction model. Our results for the UK using quite detailed disaggregated data, point to rejection of both the menu cost and the signal extraction model. Specifically, for the UK using 65 sector analysis the effect of trend inflation on RPD is statistically significant, but with a negative sign. Consistent with our US results, there is no evidence of inflation uncertainty explaining RPD.

Our methodology adopts a bivariate GARCH-M model of inflation and relative price dispersion for the UK and the US. We allow the mean and the conditional variance of inflation to have effects on RPD in order to investigate the empirical relevance of menu cost and signal extraction models. The paper contributes in the relevant literature in two ways: First, we employ a detailed disaggregated data set that better captures the effect of inflation on relative price dispersion. The level of detail in our time series, in particular for the UK, is considerable compared to recent studies. Second, we use a bivariate GARCH-M methodology that allows for asymmetric effects of inflation shocks on the volatility of inflation and RPD.[1] The approach we adopt is viewed as superior in

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[1] The development of GARCH techniques allows the measurement of inflation uncertainty by the conditional variance of inflation series.

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measuring uncertainty compared to the moving standard deviation or variance of the inflation series. This superiority arises from the possibility of allowing a separation between anticipated and unanticipated changes in inflation.[2] By using the variance or standard deviation early studies have used inflation variability instead of uncertainty.

Combining our data and the econometric contribution, there are quite significant effects for the literature. For the case of the UK and the US, our results point to the role of monetary search models. There is very little evidence in favour of either the menu cost or the signal extraction model. While we formally model both inflation and RPD uncertainty, our paper casts significant doubt on the relevance of inflation uncertainty in predicting RPD. Following the Grier and Perry (1996) methodology, we have shown that inflation uncertainty may be found to be a significant predictor of RPD (as these authors found in their study using a different data set). However, this methodology is subject to the criticism that it assumes a symmetric generalized autoregressive conditional heteroscedasticity (GARCH) model, an assumption that is strongly rejected by our data.

The paper is organized as follows. Section II. reviews the theoretical and empirical literature on the relationship between inflation and RPD. Section III. outlines the methodology. Section IV. describes the data and section V. reports the empirical results. Section VI. provides some sensitivity analysis and finally section VII. concludes.

II. Literature Review

Economic theories examining the relationship between inflation and RPD include menu cost models, signal extraction models and monetary search models. The implications of these models regarding the role of expected and unexpected inflation are different. Our focus will be on how each of these models handles expected or unexpected inflation.

1. Theoretical Models

Early studies by Mills (1927) and Graham (1930) in the area of price behaviour indicate that the variability of relative price changes increases with higher inflation. Also Vining and Elwertowski (1976) and Parks (1978) have investigated the component of inflation that is related to RPD.

Menu cost models of Sheshinski and Weiss (1977) and Rotemberg (1983) predict a positive association between RPD and expected inflation. Menu cost

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[2] Unanticipated changes would be the source of uncertainty.

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models assume that there are price adjustment costs when nominal price changes. Firms set prices according to discontinuous pricing rule (S,s); S being the high price and s being the low price. If there is inflation the real price of the firm falls from S to s. The firms try to adjust the real price to S by raising the nominal price. Each firm has a specific fixed cost or a shock and the width of the pricing rule depends on the size of these menu costs. These firm specific menu costs will cause staggered prices thus distorting relative prices and an increase in RPD. Given the existence of staggered price setting, higher inflation increases the dispersion of relative prices. The important point is that the expected part of inflation affects the width of the pricing rule band. Thus, as expected inflation increases the distorting effects of menu costs on relative prices are augmented.

Signal extraction models predict a positive relationship between unexpected inflation and RPD. Signal extraction models assume that inflation is not anticipated correctly. Firms and households get confused between absolute and relative price changes. Higher inflation uncertainty makes aggregate demand shocks harder to predict. As aggregate nominal shocks become more unpredictable, firms react with less output adjustment in response. Prices move more in each market to equate quantity demanded with less variable quantity supplied. The firms prices will be more dispersed the less firms respond to demand shocks with output changes which implies that increases in inflation uncertainty will lead to higher RPD.

Barro's (1976) model provides a rationale for the relationship between ex ante inflation uncertainty and relative price dispersion. Barro (1976) links the dispersion of relative prices to the variance of money supply using the localized markets framework employed by Lucas (1973). In the Barro (1976) model the variance of general price change and the variance of individual price change are determined endogenously. They are both determined by the variance of aggregate monetary shocks, variance of aggregate excess demand shocks and the variance of relative excess demand shocks which are all assumed to be exogenous.

Cukierman (1979) interprets Lucas's (1973) paper on the conditions of a positive relationship between the relative price and the general price level.[3] One of the comments is that if the variance of the rate of change in nominal income changes over time then there will be a positive association between the variance of relative prices and the variance of general price level. There is a condition for the variance of specific demand shocks as well. If the changes in variance of rate of change in nominal income dominate the changes in the variance of specific demand shocks, there will be a positive association.

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[3] Cukierman (1979) demonstrates in his note that Lucas's (1973) model is perfectly consistent with the finding that there is a positive association between individual price change dispersion and general price change dispersion.

In the monetary search models, the overall effect of inflation on RPD is not obvious. Reinsdorf (1994), Peterson and Shi (2004) emphasize that buyers have incomplete information about prices offered by sellers. Higher expected inflation lowers the value of fiat money, which increases sellers' market power and thereby the dispersion of prices. Higher expected inflation also raises the gains of search, which lowers sellers market power and also RPD. Head and Kumar (2005) set up a model where the effects of inflation on both price dispersion and welfare depend on whether sellers market power is increased by the lowering of the value of fiat money or the sellers market power is reduced by more search. In their model an increase in fully anticipated inflation increases dispersion by lowering the value of fiat money and raising consumers reservation levels which leads to more market power for the sellers. Since an increase in dispersion also increases search the combined effect on dispersion is ambiguous. At low levels of inflation the search effect can dominate which will lead to reduction in dispersion. At high levels of inflation the lowering of value of fiat money effect dominates which will lead to an increase in dispersion.

2. *Empirical Literature*

Early empirical literature generally finds positive or no association between inflation and price dispersion. Vining and Elwertowski (1976) find a positive association between the variability of the rate of inflation in the general level of prices and the variance of the rate of change in relative prices. They present their evidence as a contradiction to the stochastic version of the neoclassical model published by Lucas (1973). Vining and Elwertowski (1976) present their results by only providing graphical analysis of aggregate inflation and relative price dispersion. Parks (1978) runs relative price dispersion on squared inflation and reports significant coefficients for inflation square. Parks uses annual data on 12 sectors of personal consumption expenditures for the period 1930–1975. Driffil, Mizon and Ulph (1990) criticize these early works; in particular they argue that the results would not be robust if outliers are omitted. Bomberger and Makinen (1993) use Park's model and exclude energy prices and the oil shock years of 1974 and 1980 and find that inflation has no significant effect on relative price dispersion. Fischer (1981) and Taylor (1981) report similar results to Bomberger and Makinen (1993). Fischer (1981) argues that the positive association would not hold if energy and food prices are excluded and Taylor (1981) argues the same for energy shocks. In summary, the early empirical work is mainly based on linear regressions of RPD and inflation.

The recent literature provides evidence of positive, negative or no association between inflation and RPD. As the menu cost models and signal extraction models imply, some of the empirical work, like Grier and Perry (1996), Parsley (1996), Debelle and Lamont (1997), Aarstol (1999) and Jaramillo (1999) find a

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positive association between expected inflation or inflation uncertainty and RPD. Some empirical studies find a negative association in agreement with the literature of monetary search models. Reinsdorf (1994) finds a negative relationship between RPD and inflation. He explains his finding arguing that when incomplete information prevents searching consumers who encounter an unexpectedly high price from knowing whether they have drawn an overpriced seller or whether the good itself has become higher priced, increased inflation may cause downward bias as consumers guess about the location of the price distribution. Reservation prices may be too low in relation to the actual price distribution. The additional search is likely to reduce price dispersion, because more search will lead to a greater impact of deviation of markets price on sellers quantity demanded. The positive effect will dominate as inflation rises. Fielding and Mizen (2000) and Silver and Ioannidis (2001) show for several European countries that RPD decreases in inflation. Caglayan and Filiztekin (2003) and Caraballo, Dabus and Usabiaga (2006) indicate that some of the studies have shown differing impacts of inflation on RPD for high and low inflation periods and for differing inflationary country policies in support of monetary search models. Becker and Nautz (2009) in their recent work find that the impact of the expected inflation on RPD disappears when inflation expectations have been stabilized on a low level in line with monetary search models.

Some of the other studies apply different techniques to examine the relationship of inflation and RPD. Fielding and Mizen (2008) find that the inflation-RPD relationship is nonlinear in the US by using nonparametric methods. Nautz and Scharf (2006) by adopting panel threshold models, find support for threshold effects in the European link between expected inflation and RPD. Choi (2010) finds that the relationship between inflation and relative price variability in the US is nonlinear and unstable. In particular, a U-shaped relationship applies during the Great Moderation.

Another line of literature uses store level data. Caglayan, Filiztekin and Rauh (2008) use a unique price dataset collected from bazaars, convenience stores and supermarkets in Istanbul and find a positive and significant relationship between RPD and inflation and lagged RPD and unexpected product specific inflation. The authors show that price dispersion can have different relationships with different inflation measures. They note that all models contribute to the relationship of RPD and inflation, so an integrated theoretical model should be developed. Konieczny and Skrzypacz (2005) analyze the behavior of price setters in Poland during the transition period from a planned economy to market economy. They find that relative price variability increases with inflation. They also find that the effect of expected inflation is much larger than the effect of unexpected inflation.

Some studies incorporate other variables into the empirical specification. Lastrapes (2006) incorporates money supply and productivity shocks into his anal-

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ysis for US data using a VAR approach to investigate the relationship between inflation and distribution of relative commodity prices. However, Lastrapes (2006) does not include inflation uncertainty in his specification.He finds that both shocks lead to positive correlation between inflation and the dispersion of relative prices. Balderas and Nath (2007) include data of remittances for Mexican data. They find a positive relationship between inflation and relative price variability and conclude that remittances could be a factor for this relationship.

III. Methodology

1. Measuring RPD

One of the accepted measures of RPD in the literature is;

$$RPD_t = (1/n)\sum_{i=1}^{n}(\pi_{it} - \pi_t)^2 \tag{1}$$

where π_t is the aggregate inflation rate and π_{it} is the rate of change of the i^{th} price subindex. An alternative proxy used in this study (and in Grier and Perry, 1996) is the weighted relative price dispersion (WRPD) which modifies the above measure by incorporating the weights w_i of the subindices.

$$WRPD_t = (1/n)\sum_{i=1}^{n}(w_i)(\pi_{it} - \pi_t)^2 \tag{2}$$

2. GARCH Approach

We adopt a bivariate VARMA GARCH-M model (see Grier et al (2004) and Bredin et al. (2009)) in order to model inflation (π_t) and relative price dispersion (RPD_t) simultaneously. This method will simultaneously estimate equations for inflation and relative price dispersion and will take into account the conditional standard deviations as explanatory variables.

$$Y_t = \quad + \sum_{i=1}^{p}\Gamma_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q}\Theta_j \epsilon_{t-j} + \epsilon_t \tag{3}$$

In equation (3), Y_t is the 2x1 matrix including RPD and inflation, where $\epsilon_t \mid \Omega_t \sim (0, H_t)$ and Ω_t is the available information set. The choice of the GARCH-M model is made in order to take account of the likely influence of uncertainty about inflation and relative price dispersion on average inflation and relative price dispersion. The model will be estimated by the maximum likelihood method subject to the conditional covariance matrix being positive definite for all values of ϵ_t. Estimation uses a simplex to improve the starting values and then maximizes log likelihood function using Broyden, Fletscher, Goldfarb and Shanno (BFGS) algorithm. Bollerslev / Wooldridge (1992) robust standard errors are produced to account for possible nonnormality in the data. Diagonality and symmetry restrictions are tested rather than being imposed. This model nests diagonal and symmetric models. The effects of uncertainty on inflation and RPD are captured by the Ψ matrix.

$$H_t = \begin{pmatrix} h_{RPD_t} & h_{RPD,\pi,t} \\ h_{\pi,RPD,t} & h_{\pi t} \end{pmatrix}; \quad Y_t = \begin{pmatrix} RPD_t \\ \pi_t \end{pmatrix}; \quad \epsilon_t = \begin{pmatrix} \epsilon_{RPD,t} \\ \epsilon_{\pi,t} \end{pmatrix} \tag{4}$$

$$\sqrt{h_t} = \begin{pmatrix} \sqrt{h_{RPD,t}} \\ \sqrt{h_{\pi,t}} \end{pmatrix}; \quad \mu = \begin{pmatrix} \mu_{RPD} \\ \mu_\pi \end{pmatrix}; \quad \Gamma_i = \begin{pmatrix} \Gamma_{11}^i & \Gamma_{12}^i \\ \Gamma_{21}^i & \Gamma_{22}^i \end{pmatrix}, \tag{5}$$

$$\Psi = \begin{pmatrix} \Psi_{11} & \Psi_{12} \\ \Psi_{21} & \Psi_{22} \end{pmatrix}; \quad \Theta_j = \begin{pmatrix} \Theta_{11}^j & \Theta_{12}^j \\ \Theta_{21}^j & \Theta_{22}^j \end{pmatrix} \tag{6}$$

$$H_t = C_0^{*'} C_0^* + B_{11}^{*'} H_{t-1} B_{11}^* + A_{11}^{*'} \epsilon_{t-1} \epsilon_{t-1}' A_{11}^* + D_{11}^{*'} \xi_{t-1} \xi_{t-1}' D_{11}^* \tag{7}$$

Ψ_{12} represents our measure for the impact of inflation uncertainty on RPD. Positive and significant values will provide support for the signal extraction models.[4] H_t is the conditional covariance matrix specified in quadratic form in equation (7) to ensure positive definiteness. The conditional standard deviations are $\sqrt{h_{RPD,t}}$ and $\sqrt{h_{\pi,t}}$. The conditional covariance matrix H_t specification follows the standard BEKK model supplemented by the final term which takes account of possible asymmetry of the impact of shocks on the conditional variances. ξ_t is a vector defined as where $\xi_{RPD,t}$ is the positive RPD shock defined as the max($\epsilon_{RPD,t}$,0) and $\xi_{\pi,t}$ is the positive inflation shock defined as the max $(\epsilon_{\pi,t}, 0)$. The positive innovations regarding inflation (and potentially RPD) can be viewed as bad. A literature examining asymmetry for inflation is well established and there is clear empirical evidence, e.g. Bredin and Fountas (2009). If there was no asymmetry present, then the coefficient matrix D would not be statistically significant.

$$C_0^* = \begin{pmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{pmatrix} \; B_{11} = \begin{pmatrix} \beta_{11}^* & \beta_{12}^* \\ \beta_{21}^* & \beta_{22}^* \end{pmatrix} \tag{8}$$

$$A_{11}^* = \begin{pmatrix} \alpha_{11}^* & \alpha_{12}^* \\ \alpha_{21}^* & \alpha_{22}^* \end{pmatrix} \; D_{11}^* = \begin{pmatrix} \delta_{11}^* & \delta_{12}^* \\ \delta_{21}^* & \delta_{22}^* \end{pmatrix} \; \xi_t^2 = \begin{pmatrix} \xi_{RPD,t}^2 \\ \xi_{\pi,t}^2 \end{pmatrix} \tag{9}$$

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[4] When the effect of inflation is not significant.

IV. Data Issues and Construction

The UK price indices are sourced from National Statistics Online (NSO). We have two datasets for price indices, differing by disaggregation levels. The relatively less disaggregated dataset of 24 subsectors consists of the aggregate index of the output of manufactured goods (PLLU) and the subindices making up output of manufactured goods (PLLU) over the period of January 1991 to May 2008.[5] For the more disaggregated data we use 65 sub-sectors with 2 digit standard industrial trade classification (SITC) codes which we match from UK price indices. We distribute the weights from output of manufactured goods price index (PLLU) to the major 1 digit codes and then assume equal weights for 2 digit subsectors. The sample for the more disaggregated data is from January 1979 to May 2008. The weights are reported in the Appendix, Table 2.

For the case of the US, the monthly measure of RPD is calculated using equation (2) from the US producer price indices. We source the producer price indices from the Bureau of Labor Statistics (BLS) website. The sample period is January 1978 to May 2008. We use the two digit SITC subsectors, with the price indices matched. The aggregate producer price index (PPI) and the aggregate consumer price index (CPI) are from International Financial Statistics (IFS).[6,7]

1. Data Analysis

Inflation is measured by the annualized monthly difference of the logarithm of the producer price index PPI $[\pi_t = \log((PPI_t)/PPI_{t-1})*1200]$. Summary statistics on inflation and RPD are reported in Table 1 for both the UK (24 sub-sectors) and the US. These statistics include results on skewness, kurtosis and the Jarque-Bera normality test. The reported results provide evidence against normality for both inflation and RPD. Similar results are obtained using the UK data with 65 sectors. We test for the stationarity properties of the data

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[5] In correspondence with the NSO, we requested the following series; POLB, POLC, RPUW, POLG, POLH, POLI, POLJ, POLL and RPUZ. NSO have indicated that some of the series are *disclosive*. Instead of RPUW (gross sector output division 23 including duty) we use RPVU (gross sector output division 232 including duty) as the former is confidential. In addition, we also use POKQ instead of base metals (POLJ) as base metals is disclosive. POKQ contains both 'base metals' (POLJ) and 'fabricated metal products, except machinery and equipment'. The subindex weights for output of manufactured goods (PLLU) price index as of 2005 are reported in the Appendix, Table 1.

[6] Given the data availability issues, the index weights are adopted from the UK data.

[7] The large decline in PPI (plant and animal fibers) from July to August 1986 can be traced to a fall in raw cotton prices by 59.2% in August 1986. Within a year, price levels for cotton rebounded. The BLS has confirmed that the data and the above explanation is accurate.

Table 1

Summary Statistics

	UK		US	
	RPD	INF	RPD	INF
Mean	169	2.04	978	3.46
Skewness	2.91	0.87	6.13	–0.03
Kurtosis	10.49	4.37	59.01	2.49
JB Normality Test	1322	203	54952	94

Table 2

Unit Root Tests

	UK		UK (65)		US	
	RPD	INF	RPD	INF	RPD	INF
Dickey Fuller	–9.06	–8.32	–13.05	–10.97	–15.14	–14.02
Phillips Perron	–9.34	–8.41	–13.44	–11.21	–15.36	–14.22

Dickey Fuller and Phillips Perron unit root test results are presented for the US data and for the UK data with 24 sectors and the UK data with 65 sectors.

using the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests with 4 lags and we present the test statistics in Table 2[8]. The results of these tests indicate that we can treat the inflation rate and the RPD term in each country as a stationary processes. Our summary statistics and our unit root results are consistent with existing empirical evidence, e.g. Grier and Perry (1996).

We use both the Akaike Information Criteria (AIC) and the Schwarz Bayesian (SBC) criteria to test for the lag lengths p and q in the VARMA models. [9]

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[8] The KPSS stationarity test has also been used for robustness and results are available upon request. The conclusion regarding the stationarity of the series remains unchanged. In addition, we have calculated autocorrelations of the variables and the squares of the variables and concluded that the GARCH modeling strategy is appropriate.

[9] For UK large sample, the AIC selects 6 lags for both the AR and the MA terms, while the SBC selects (5,6). For the UK reduced sample (sample staring in 1991), the AIC selects (1,6), while the SBC selects (1,1). For the case of the US, the AIC selects (6,6) and the SBC selects (1,2).

V. Empirical Results

In this section we present the estimation results for the UK and the US.

1. UK Results: 65 Sector Analysis

The results presented in Table 3 use 65 sectors and a VARMA GARCH-M model, mean effects in the top panel and coefficient values from the multivariate GARCH model presented in the lower panel. The A, B, C and D matrices are formally defined in the methodology section. The results show that the lagged inflation effect on RPD has a negative sign and statistically significant. The lagged inflation term represents trend inflation and implies evidence counter to the menu cost model. Our results for the UK are consistent with those reported by Reinsdorf (1994). The inflation uncertainty effect on RPD is not statistically significant (at conventional levels) and implies that there is no evidence in favour of the signal extraction model. While formal tests of the model are not consistent with recent evidence for the US (e.g. Grier and Perry (1996)), our reported results do indicate similar relationships for the lagged dependent varia-

Table 3

Bivariate GARCH-M UK – 65 Sectors

GARCH(1,1) MODEL			RPD_{t-1}		INF_{t-1}		$\sqrt{h_{RPD,t}}$		$\sqrt{h_{\pi,t}}$
RPD_t	119.707***	+	0.63***	–	21.867***	–	0.208***	–	1.454
	(19.060)		(14.111)		(–31.913)		(–7.815)		(–1.607)
π_t	1.589***	–	0.005***	+	0.685***	–	0.000	+	0.002
	(9.634)		(–18.409)		(25.186)		(–0.10)		(0.164)

Notes: $\sqrt{h_{rpd,t}}$ = Standard deviation of RPD, $\sqrt{h_{\pi,t}}$ = Standard deviation of Inflation. T-statistics are in parentheses.

$$A = \begin{bmatrix} 2.665^{***} & 0.002 \\ (7.687) & (1.336) \\ 3.120^{***} & 0.280^{***} \\ (7.310) & (3.591) \end{bmatrix} \qquad B = \begin{bmatrix} 0.161^{***} & -0.000 \\ (3.461) & (-1.258) \\ -0.329^{***} & 0.895^{***} \\ (-3.787) & (36.146) \end{bmatrix}$$

$$D = \begin{bmatrix} -0.638 & -0.000 \\ (-1.228) & (-0.379) \\ -0.624 & 0.367^{***} \\ (-0.961) & (4.275) \end{bmatrix} \qquad C = \begin{bmatrix} 0.393^{***} & -0.924 \\ (2.758) & (-4.98)^{***} \\ 0 & 0.035 \\ & (0.205) \end{bmatrix}$$

Table 4

UK – Specification Tests – 65 Sectors

NULL	TEST	Significance Level	Chisq
Diagonal VARMA	$H_0 = \Gamma_{12}^{i} = \Gamma_{21}^{i} = \theta_{12}^{i} = \theta_{21}^{i} = 0$	0.00	Chisq(10)=2119
No GARCH	$H_0 = \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ for all i and j	0.00	Chisq(12)=586
No GARCH-M	$H_0 = \Psi_{ij} = 0$ for all i and j	0.00	Chisq(4)=135
No Asymmetry	$H_0 = \delta_{ij} = 0$ for all i and j	0.00	Chisq(4)=19.13
Diagonal GARCH	$H_0 = \alpha_{12}^{*} = \alpha_{21}^{*} = \beta_{12}^{*} = \beta_{21}^{*} = \delta_{12}^{*} = \delta_{21}^{*} = 0$	0.00	Chisq(6)=106.06

Notes: The results of Chi square tests are reported in this table for UK with 65 sectors.

bles and the role of uncertainty on mean relationships. In addition our GARCH coefficients are consistent with previous empirical studies (e.g. Bredin and Fountas (2009)). In particular the extent of inflation uncertainty persistence (0.895) and most importantly for our approach the importance of inflation asymmetry (0.379). The significance of this coefficient for inflation shows that positive inflation shocks raise uncertainty about inflation more than negative shocks do. There is also no evidence of asymmetry for the RPD. Taking the results on board, our empirical model implies evidence in favour of the monetary search models. Given, the level of detail in our data set it is important to evaluate the validity of our empirical model before any further analysis is completed.

A series of formal specification tests are presented in Table 4 and imply consistent evidence that our estimated model is correctly specified. Specifically, Table 4 indicates all nested models estimated are rejected by the data. First, the diagonal VARMA is rejected meaning that the AR and MA terms of RPD enter into the conditional mean equation for inflation and vice versa. Second, we can reject the null of no GARCH effects, i.e., the joint significance of A_{11}^{*}, B_{11}^{*}, D_{11}^{*} provides evidence of heteroskedastic conditional variance. Third, the joint significance of the Ψ matrix indicates presence of GARCH-M effects. Thus, the conditional standard deviation would appear in the mean equation. Fourth, we also reject the null of no asymmetry by the joint testing of matrix D_{11}^{*} implying that the covariance process is asymmetric. Finally, the diagonal GARCH is rejected. The null hypothesis that the off diagonal elements in matrix A_{11}^{*} (lagged errors), matrix B_{11}^{*} (lagged conditional variance), and matrix D_{11}^{*} are all zero is

Table 5

Bivariate GARCH-M UK – 24 Sectors

GARCH(1,1) MODEL		RPD_{t-1}	INF_{t-1}	$\sqrt{h_{RPD,t}}$	$\sqrt{h_{\pi,t}}$
RPD_t	95.465***	– 0.037	– 2.784	+ 0.555*	– 8.592
	(2.691)	(–0.193)	(–0.499)	(2.204)	(–0.823)
π_t	2.756***	– 0.010***	– 0.441***	+ 0.023***	– 0.734***
	(6.559)	(–3.373)	(–3.692)	(6.423)	(–4.061)

Notes: $\sqrt{h_{rpd,t}}$ = Standard deviation of RPD, $\sqrt{h_{\pi,t}}$ = Standard deviation of Inflation. T-statistics are in parentheses.

$$A=\begin{bmatrix} 0.608^{***} & 0.002 \\ (10.335) & (1.436) \\ 17.233^{***} & 0.520^{***} \\ (8.454) & (5.153) \end{bmatrix} \qquad B=\begin{bmatrix} 0.695^{***} & -0.007^{***} \\ (20.629) & (-7.518) \\ -0.746 & 0.186 \\ (-0.194) & (1.483) \end{bmatrix}$$

$$D=\begin{bmatrix} 0.557^{***} & 0.017^{***} \\ (3.226) & (4.080) \\ -10.285 & 0.550^{***} \\ (-1.898) & (2.291) \end{bmatrix} \qquad C=\begin{bmatrix} 21.390 & 1.912^{***} \\ (1.797) & (7.674) \\ 0 & -0.001 \\ & (-0.035) \end{bmatrix}$$

strongly rejected. In summary, the chosen model seems to be well specified for the UK, using 65 sectors[10].

2. *UK Results: 24 Sector Analysis*

Having established the validity of our empirical model, we now consider the case of the 24 sector analysis. While, we certainly lose detailed data dynamics, the reduced disaggregation is consistent with the data applied by the vast majority of the previous studies. The results presented in Table 5 refer to the less disaggregated dataset starting in January 1991. However, as can be seen from the results, our findings are consistent with those reported for the 65 sector case. We find both the effects of lagged inflation and inflation uncertainty on RPD are not statistically significant. Again there is consistent evidence that there is

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[10] We have also performed Granger causality tests in a two-step procedure to estimate the effects of unertainty on inflation and RPD. The results (available upon request) support the paper's findings.

Table 6

UK – Specification Tests – 24 Sectors

NULL	TEST	Significance Level	Chisq
Diagonal VARMA	$H_0 = \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	0.00	Chisq(4) = 37
No GARCH	$H \ = \alpha_{ij} = \beta_{ij} = \delta_{ij} =$ for all i and j	0.00	Chisq(12) = 2017
No GARCH-M	$H_0 = \Psi_{ij} = 0$ for all i and j	0.00	Chisq(4) = 45
No Asymmetry	$H_0 = \delta_{ij} = 0$ for all i and j	0.00	Chisq(4) = 22
Diagonal GARCH	$H_0 = \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	0.00	Chisq(6) = 237

Notes: The results of Chi square tests are reported in this table for UK with 24 sectors.

little to support either the menu cost model or the signal extraction model for the UK. Our results using the reduced level of decomposition are consistent with results reported by Eden (2001) and Baharad and Eden (2004). As in the 65 sector case, all evidence points to an estimated model that is correctly specified. Again we find evidence of inflation asymmetry. In particular all nested models tested, presented in Table 6, are rejected.

3. *US Results*

The results in Table 7 show that inflation affects RPD significantly and the sign of the effect is positive. In contrast, inflation uncertainty does not have a significant effect on RPD. These results imply that there is support for menu cost models in the US case. Again our US results run counter to the recent evidence on RPD for the US (e.g. Grier and Perry (1996)). However, our results on inflation uncertainty dynamics are consistent with recent evidence (e.g. Bredin and Fountas (2009)). In particular the extent of inflation uncertainty persistence (0.910) and most importantly for our approach the importance of inflation asymmetry (0.509). As was the case for the UK, positive inflation shocks in the US raise uncertainty about US inflation more than negative shocks do. The specification tests, presented in Table 8, for the US reveal that the chosen model is well specified. Again, all nested models tested are rejected.

Table 7

US Bivariate GARCM-M

GARCH(1,1) MODEL			RPD_{t-1}		INF_{t-1}		$\sqrt{h_{RPD,t}}$		$\sqrt{h_{\pi,t}}$
RPD_t	–28.186	+	1.144***	+	24.616***	–	0.105***	–	8.816
	(–0.505)		(21.845)		(3.960)		(–4.455)		(–1.467)
π_t	5.169*	–	0.003	–	0.513***	–	0.000*	+	0.205
	(2.394)		(–1.815)		(–3.228)		(–2.014)		(0.549)

Notes: All the error lags terms for RPD mean equation are significant but are not reported here. $\sqrt{h_{rpd,t}}$ = Standard deviation of RPD, $\sqrt{h_{\pi,t}}$ = Standard deviation of Inflation, with t-statistics in parentheses.

$$A = \begin{bmatrix} -1.950^{***} & 0.000 \\ (-8.695) & (1.437) \\ -5.462 & -0.131 \\ (-0.770) & (-1.627) \end{bmatrix} \qquad B = \begin{bmatrix} -0.037 & 0.001 \\ (-0.778) & (1.444) \\ 21.598^{***} & 0.910^{***} \\ (3.288) & (53.224) \end{bmatrix}$$

$$C = \begin{bmatrix} 226.722^{***} & -1.361^{***} \\ (5.494) & (-6.183) \\ 0 & 0.00 \\ & (0.00) \end{bmatrix} \qquad D = \begin{bmatrix} -0.168 & -0.000 \\ (-0.558) & (-0.268) \\ 8.477 & 0.509^{***} \\ (0.284) & (6.012) \end{bmatrix}$$

Table 8

US – Specification Tests

NULL	TEST	Significance Level	Chisq
Diagonal VARMA	$H_0 = \Gamma_{12}^i = \Gamma_{21}^i = \theta_{12}^i = \theta_{21}^i = 0$	0.00	Chisq(10) = 39
No GARCH	$H_0 = \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ for all i and j	0.00	Chisq(12) = 12414
No GARCH-M	$H_0 = \Psi_{ij} = 0$ for all i and j	0.00	Chisq(4) = 22
No Asymmetry	$H_0 = \delta_{ij} = 0$ for all i and j	0.00	Chisq(4) = 47
Diagonal GARCH	$H_0 = \alpha_{12}^* = \alpha_{21}^* = \beta_{12}^* = \beta_{21}^* = \delta_{12}^* = \delta_{21}^* = 0$	0.02	Chisq(6) = 15

Notes: The results of Chi square tests are reported in this table.

VI. Sensitivity Analysis

For comparison purposes, we also apply the bivariate GARCH methodology suggested by Grier and Perry (1996). Given, the quality of our data set for the UK, the additional sensitivity analysis is performed solely on the UK data. In other words, we use UK data and estimate the near VARMA GARCH-M model. This model is quite restrictive relative to the more general model we estimated previously as it assumes symmetry and considers the conditional variance of RPD as constant. To determine a suitable empirical model, we examine the autocorrelation and partial autocorrelation functions and also use the AIC and SBC criteria for lag selection for inflation and relative price dispersion. For UK inflation; the PACF has a spike at lag 12 indicating the importance for the AR term. The ACF has spikes at lag 11, 12, 23 and 24 indicating the importance for a MA term. Using the ACF and PACF along with AIC and SBC criteria, we end up with the following model:

$$RPD_t = \gamma_0 + \gamma_1 RPD_{t-1} + \gamma_2 \nu_{t-1} + \gamma_3 \pi_{t-1}^2 + \gamma_4 \sigma_{\varepsilon t}^2 + \nu_t \tag{10}$$

$$\pi_t = \beta_0 + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-12} + \beta_3 \varepsilon_{t-12} + \beta_4 \varepsilon_{t-24} + \varepsilon_t \tag{11}$$

We present the results in Table 9. Trend inflation is negatively significant and inflation uncertainty is positively significant. Hence, both trend inflation and inflation uncertainty seem to predict RPD.

Table 9

GARCH-M (Grier and Perry (1996) – UK

					RPDLAG		INFSQLAG		STDINF		RPDERRLAG
RPD_t	=	–	219	+	0.14	–	4.79	+	135	–	0.1
			(–377***)		(18***)		(–124***)		(463***)		(–19***)
π_t	=				INFLAG		INFLAG(11)		INFERRLAG12		INFERRLAG24
			1.3	+	0.16	+	0.12	+	0.1	+	0.01
			(73***)		(58***)		(51***)		(162***)		(67***)

VII. Conclusion

In this paper, we employ a bivariate VARMA -GARCH-M model of inflation and relative price dispersion for the UK and the US. We allow for both the mean and conditional variance of inflation to have effects on RPD in order to investigate the theories implied by menu cost and signal extraction models. The main contribution of the paper lies first, in the adoption of a detailed disaggregated data set, and second, in the econometric methodology based on an asymmetric bivariate BEKK model.

We find that trend inflation in most cases is significant in predicting RPD. However, the sign of the effect differs across countries as it is negative in the UK when using 65 sectors (insignificant when using 24 sectors) and positive in the US. Hence, it is only the US that we find evidence for the menu cost model. We find that in all cases inflation uncertainty is insignificant in explaining RPD. Hence, signal extraction models are not supported by our data for two reasons. First, because they predict no inflation effect on RPD (a result not supported by our data) and second, they predict that inflation uncertainty affects positively RPD, a result not supported by our data either. Hence, our paper casts significant doubt on the relevance of inflation uncertainty in predicting RPD. Following the Grier and Perry (1996) methodology, we have shown that inflation uncertainty may be found to be a significant predictor of RPD (as these authors found in their study using a different data set). However, this methodology is subject to the criticism that it assumes a symmetric GARCH model, an assumption that is strongly rejected by our data.

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Appendix

Table 1

UK Price Index Weights for PLLU

Explanation	*Code*	*Final Weights*
Mineral Waters And Soft Drinks	PPFE	1.2
Food Products Excl Beverages	RBGD	14.2
Tobacco Products Including Duty	RPUS	3.1
Textiles	POKZ	3.1
Wearing Apparel; Furs	POLA	6.8
Leather And Leather Products	POLB	1.7
Wood And Products Of Wood And Cork (Except Furniture)*,	POLC	1.1
Pulp, Paper And Paper Products	POLD	1.8
Printed Matter And Recorded Media	POLE	5.1
Petroleum Products Including Duty	RPUW	8.8
Chemicals, Chemical Products And Man-Made Fibres	POLG	7.7
Rubber And Plastic Products	POLH	2.8
Other Non Metallic Mineral Products	POLI	2.9
Base Metals And Fabricated Metal Products, Except Machinery And Equipment	POKQ	2.4
Machinery And Equipment Nec	POLL	3.4
Office Machinery And Computers	POLM	1.5
Electrical Machinery And Apparatus Nec	POLN	1.3
Radio, Television And Communication Equipment And Apparatus	POLO	3.6
Medical Precision And Optical Instruments, Watches And Clocks	POLP	2.3
Motor Vehicles, Trailers And Semi Trailers	POLQ	8.9
Other Transport	POLR	2.5
Furniture ; Other Manufactured Goods Nec	POLS	6.2
Recovered Secondary Raw Materials	QTBM	1.5
Alcoholic Beverages	RPUZ	6.1

Table 2

Sector Codes and Weights

SITC	Sectors	Weights	PPIW Codes UK
0	*Food and live animals*	*14.2*	*RBGD*
00	Live animals other than animals of Division 03	1.42	
01	Meat, meat preparations	1.42	
02	Dairy products, birds eggs	1.42	
03	Fish, crustaceans, molluscs and preparations thereof	1.42	
04	Cereals, cereal preparations	1.42	
05	Vegetables, fruit	1.42	
06	Sugar, sugar preparation , honey	1.42	
07	Coffee, tea cocoa, spices, manufactures thereof	1.42	
08	Feeding stuff for animals (excl. unmilled cereals)	1.42	
09	Miscellaneous edible products, preparations	1.42	
1	*Beverages and tobacco*	*10.4*	*RPUS,PPFE,RPUZ*
11	Beverages	5.2	
12	Tobacco, tobacco manufactures	5.2	
2	*Crude materials, inedible, except fuels*	*14.3*	*POKZ,POLA,POLC,POLD,QTBM*
21	Hides, skins, furskins, raw	1.59	
22	Oil seeds, oleaginous fruits	1.59	
23	Crude rubber (include synthetic, reclaimed)	1.59	
24	Cork, wood	1.59	
25	Pulp, waste paper	1.59	
26	Textile fibres, their wastes	1.59	
27	Crude fertilisers, minerals, excl. coal, petroleum etc.	1.59	
28	Metalliferous ores, metal scrap	1.59	
29	Crude animal, vegetable materials	1.59	
3	*Mineral fuels, lubricants and related products*	*8.8*	*RPUW*
32	Coal, coke, briquettes	2.2	
33	Petroleum, petroleum products, related materials	2.2	
34	Gas, natural, manufactured	2.2	
35	Electric current	2.2	
4	*Animal and vegetable oils, fats and waxes*	*0*	
41	Animal oils, fats		
42	Fixed vegetable fats, oils		
43	Animal or vegetable materials		
5	*Chemicals and related products*	*7.7*	*POLG*
51	Organic chemicals	0.86	
52	Inorganic chemicals	0.86	
53	Dyeing, tanning , coloring materials	0.86	
54	Medical , pharmaceutical products	0.86	
55	Essential oils, perfume materials, toilet, cleansing preps	0.86	
56	Fertilisers (other than those of Division 27)	0.86	
57	Plastics in primary forms	0.86	
58	Plastics in non-primary forms	0.86	
59	Chemical materials , products	0.86	

(Continue next page)

Table 2 (continued)

SITC	Sectors	Weights	PPIW Codes UK
6	*Manufactured goods classified chiefly by material*	*14.9*	*POLB,POLE,POLH,POLI,POLK, POLJ*
61	Leather, leather manufactures, dressed furskins	1.66	
62	Rubber manufactures	1.66	POLH
63	Cork, wood manufactures (excl. furniture)	1.66	
64	Paper, paperboard, articles thereof	1.66	
65	Textile yarn, fabrics, made-up articles, related products	1.66	
66	Non-metallic mineral manufactures	1.66	POLI
67	Iron, steel	1.66	
68	Non-ferrous metals	1.66	POLK
69	Manufactures of metals	1.66	POLJ
7	*Machinery, transport equipment*	*21.2*	*POLL,POLM,POLO,POLN, POLQ,POLR*
71	Power generating machinery , equipment	2.36	
72	Machinery specialised for particular industries	2.36	
73	Metalworking machinery	2.36	
74	General industrial machinery, equipment, parts	2.36	
75	Office machines, automatic data processing machines	2.36	POLM
76	Telecommunications , sound equipment	2.36	POLO
77	Electrical machinery, apparatus, appliances, parts	2.36	POLN
78	Road vehicles (include. air-cushion vehicles)	2.36	POLQ
79	Other transport equipment	2.36	POLR
8	*Miscellaneous manufactured articles*	*8.5*	*POLS,POLP*
81	Prefab buildings, plumbing, electrical fixtures, fittings	1.06	
82	Furniture, parts thereof, bedding, cushions etc	1.06	POLS
83	Travel goods, handbags, similar containers	1.06	
84	Articles of apparel, clothing accessories	1.06	
85	Footwear	1.06	
87	Professional, scientific, controlling apparatus	1.06	
88	Photographic apparatus, optical goods, watches clocks	1.06	POLP
89	Miscellaneous manufactured articles	1.06	
90	*Commodities and transactions not classified elsewhere*	*0*	
91	Postal packages not classified according to kind		
93	Special transactions and commodities not classified according to kind		
96	Coin (other than gold coin), not being legal tender		
97	Gold, non-monetary (excluding gold ores and concentrates)		
98	Gold coin and monetary gold		
99	All other commodities and transactions		
101	All Other	0	
TOTAL		100	