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

Gulnihal Aksoy
University College Dublin, IRELAND

Don Bredin
University College Dublin, IRELAND

Keith Cuthbertson
City University, UK

Stilianos Fountas*
University of Macedonia, GREECE

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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 and negatively in the UK. Second, inflation uncertainty is in most cases insignificant in explaining relative price dispersion, thus casting doubt on the empirical relevance of the signal extraction models.

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*Department of Economics, University of Macedonia, Thessaloniki, GREECE, Tel: +30-2310-891774, fax: +30-2310-891292, e-mail:sfountas@uom.gr

1 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) can be thought as the variance of the rate of change in relative price levels. Menu cost models predict that inflation increases relative price dispersion while the signal extraction models predict inflation uncertainty increases relative price dispersion. Monetary search models 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.

Previous studies that have examined the relationship between inflation and RPD have used relatively low levels of disaggregation. In this paper, we will examine the relationship between RPD, inflation and inflation uncertainty employing a highly-disaggregated price index data set. Our econometric approach employs 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 disprsion. Second, we use a bivariate GARCH-M methodology that allows for asymmetric effects of inflation shocks on the volatility of inflation and RPD.

As mentioned ealier, one innovation of the present study in relation to the literature is the novelty of our data set. The primary issue underlying index aggregation is the need to avoid multiple counting effects that distort price movement analysis. To get around this, statistics bureaus use several ways to calculate the price index data. We use the industry based data for the UK which is one of them. An industry approach to stage of processing assigns the entire output of an industry to a specific stage based on some empirical rule.[1] We use commodity based producer price index for US. We make use of two data sets. First, for the US and the UK we use 2 digit SITC codes with 65 subsectors which make up 10 major sectors. We match the producer price indices of the UK and the US subsectors with the SITC codes. We use the price index weights from a UK data of 24 sectors and adopt it to the UK and the US with 65 sectors. Using the United Nations standard trade classification 'SITC' codes as the basis, we match the relevant actual UK subsectors index weights to the SITC codes.[2] We assume varying index

[1] For example, if 75 percent of the output of an industry goes to final demand then the industry is classified in finished goods.

[2] We have actual weights of the price index data for the UK price data with 24 subsectors. We match these weights to the SITC major codes.

weights for 10 major codes and then distribute the weights evenly among the subsectors making up the major codes. The disaggregation is important as aggregation of the subsectors indices might cover up the real effects of inflation on relative price dispersion. Positive and negative deviations might cancel each other in the aggregation process. Thus, disaggregation will better reflect the influence of inflation on relative price dispersion. In our second data set, we have 24 subsectors for the UK that make up an aggregate manufacturing output index and the relevant subsector index weights. In this particular dataset, we use actual price index weights for the UK to derive the RPD series. Other studies have used equal weights or sectoral GDP weights as a proxy. The quality of our datasets for the UK and the US is superior to earlier studies in this area as it contains more information.

The development of Generalized Autoregressive Conditional Heteroscedasticity (GARCH) techniques allows the measurement of inflation uncertainty by the conditional variance of inflation series. This technique represents a superior approach to measure 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.[3] By using the variance or standard deviation early studies have used inflation variability instead of uncertainty.

There are various methodological approaches one may choose from to investigate the empirical relationship between inflation and RPD. First, one may use a univariate GARCH framework where in the first step the conditional variances of inflation and RPD are estimated independently from each other and then, in the second step, Granger causality tests are performed. Alternatively, as in our study, a simultaneous approach can be adopted where a bivariate GARCH in mean (GARCH-M) is estimated to provide estimates of the conditional variances and at the same time test for the impact of inflation uncertainty on RPD. 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, inflation uncertainty is marginally insignificant in explaining RPD.

This paper is organized as follows. Section 2 reviews the theoretical and empirical literature on the relationship between inflation and RPD. Section 3 outlines the methodology. Section 4 describes the data and reports the empirical results. Finally, Section 5 concludes.

2 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.

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

2.1 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 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.[4] 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

[4] 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.

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.

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. Reinsdorf (1994) finds a negative relationship between unexpected inflation and RPD and a positive effect between expected inflation and 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.

2.2 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 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. Reinsdorf (1994) supports his finding with the explanation 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 analysis 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.

3 Methodology

3.1 Measuring RPD

One of the accepted measures of relative price dispersion in the literature (RPD_t) 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 which modifies the above measure by incorporating the weights of the subindices.

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

3.2 GARCH approach

We adopt a VARMA bivariate GARCH-M model (see Grier et al (2004) and Bredin et al.(2009)). We show below how 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.

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

In equation (3) Y_t is the 2x1 matrix including RPD and inflation where $\epsilon_t|\Omega_t \sim (0, H_t)$ and Ω_t is the information set available. 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 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 Ψ matrix.

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

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

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

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

Ψ_{12} tests for the impact of inflation uncertainty on RPD. Positive and significant values will provide support for the signal extraction models.[5] 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.

$$C_0^* = \begin{pmatrix} c^*_{11} & c^*_{12} \\ 0 & c^*_{22} \end{pmatrix} \quad B_{11} = \begin{pmatrix} \beta^*_{11} & \beta^*_{12} \\ \beta^*_{21} & \beta^*_{22} \end{pmatrix} \tag{8}$$

$$A_{11}^* = \begin{pmatrix} \alpha^*_{11} & \alpha^*_{12} \\ \alpha^*_{21} & \alpha^*_{22} \end{pmatrix} \quad D_{11}^* = \begin{pmatrix} \delta^*_{11} & \delta^*_{12} \\ \delta^*_{21} & \delta^*_{22} \end{pmatrix} \tag{9}$$

[5] When the effect of inflation is not significant

4 Data and Empirical Results

4.1 UK Data

The price indices are sourced from National Statistics Online (NSO). We have two datasets for price indices for UK, differing by disaggregation levels. The more disaggregated data is from January 1979 to May 2008. For the more disaggregated data we use 65 subsectors with 2 digit SITC codes which we match from price indices of UK at best. We distribute the weights from the output of manufactured goods price index (PLLU) to the major 1 digit codes and then assume equal weights for 2-digit subsectors.

The relatively less disaggregated dataset of 24 subsectors consists of the PLLU and its subindices over the period of January 1991 to May 2008. 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. Also we use POKQ instead of base metals (POLJ) as POLJ is disclosive. POKQ contains both 'base metals' (POLJ) and 'fabricated metal products, except machinery and equipment' (POLK).[6] The subindex weights for PLLU as of 2005 are reported in the appendix in Table 11.

4.2 US Data

The monthly measure of RPD is calculated from the producer price indices using equation (2) . We source the US producer price indices from the Bureau of Labor Statistics (BLS) website over the period of January 1978 to May 2008. We use the two digit SITC subsectors which we match to the price indices at best. The aggregate producer price index (PPI) is taken from International Financial Statistics (IFS).[7]

4.3 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. These statistics include results on skewness, kurtosis and the Jarque-Bera normality test which provide evidence against normality in inflation and RPD. Similar results are obtained using the UK data with 65 sectors.

We test for the stationarity properties of the data using the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests with 4 lags and we present the test statistics in Table 2. The results of these tests indicate that we can treat the inflation rate and the relative price dispersion

[6] We combine POLJ and POLK and use only POKQ instead.
[7] The index weights are adopted from the UK data.

in each country as stationary processes. We use the (Akaike) AIC and (Schwarz) SBC criteria to test for the lag lengths p and q in the VARMA models. [8]

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.

4.4 Empirical Results

In this section we present the estimation results for the UK and the US.[9]

4.4.1 UK General Model - VARMA(1,4) Bivariate GARCH-M - (65 sectors)

The results presented in Table 3 use 65 sectors and a VARMA (1,4) GARCH-M. The results show that the lagged inflation effect on RPD is negative and significant. The inflation uncertainty effect on RPD is marginally insignificant. These results are consistent with the implications of monetary search models.

The specification tests are presented in Table 8 and imply that the estimated model is correctly specified. First, the diagonal VARMA is rejected meaning that the AR and MA terms of RPD enter into the conditional mean equation for INF 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 for heteroskedastic conditional variance. Third, the joint significance of the Ψ matrix

[8] The first one is RPD and the second one is inflation. For UK AIC selects (6,6) and SBC selects (5,6). SBC (1,6) is also very close. For data starting from 1991 AIC selects (1,6) SBC selects (1,1) again SBC for (1,6) is very close. For US AIC selects (6,6) and SBC selects (1,2) when whole range of data is used.

[9] Trend inflation is proxied by lag inflation.

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

Table 3: UK - AR=1 MA=4. GARCH(1,1) - M

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: RPD_t =RPD ; RPD_{t-1} =RPD LAG ; π_t =Inflation= ; π_{t-1} = Inflation Lag ; $\sqrt{h_{rpd,t}}$= Standard deviation of RPD $\sqrt{h_{\pi,t}}$ =Standard deviation of Inflation. t-statistics are in parentheses.

4.4.2 UK General Model - VARMA(1,1) Bivariate GARCH-M - (24 Sectors)

The results presented in Table 4 refer to the less disaggregated dataset starting from January 1991.[10] Both the effects of lagged inflation and inflation uncertainty on RPD are statistically insignificant leading to the conclusion that there is no support for menu cost models or signal extraction models for UK with this dataset. As in the previous case, the estimated model is correctly specified. All nested models tested (see Table 9) are rejected.

Table 4: UK - AR=1 MA=1 GARCH(1,1)-M

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: RPD_t =RPD ; RPD_{t-1} =RPD LAG ; π_t =Inflation= ; π_{t-1} = Inflation Lag ; $\sqrt{h_{rpd,t}}$= Standard deviation of RPD ; $\sqrt{h_{\pi,t}}$ =Standard deviation of Inflation. t-statistics are in parentheses.

[10] In the estimation procedure the data is trimmed in the beginning for 20 months.

4.4.3 UK- Grier and Perry (1996) Approach

We start with simple regressions where we regress RPD on measures of trend inflation, such as squared inflation and lagged squared inflation. This approach omits inflation uncertainty as a potential determinant of RPD. Previous studies such as Parks (1978) and Grier and Perry (1996) followed a similar approach. In Table 7 we present the results for OLS regressions for the relationship between relative price dispersion and inflation for the UK and the US. The initial regressions indicate a positive and significant effect of inflation on RPD. However, such an approach is quite naive as it omits inflation uncertainty as a potential predictor of RPD according to signal extraction models.

For comparison purposes, we also apply the bivariate GARCH methodology suggested by Grier and Perry (1996). 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 the best mean equations, we first check 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:

$$RPD_t = \gamma_0 + \gamma_1 RPD_{t-1} + \gamma_2 \upsilon_{t-1} + \gamma_3 \pi^2_{t-1} + \gamma_4 \sigma^2_{\varepsilon t} + \upsilon_t \tag{10}$$

$$\pi_t = \beta_0 + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-12} + \beta_3 \varepsilon_{t-12} + \beta_4 \varepsilon_{t-24} + \beta_5 \varepsilon_t \tag{11}$$

We present the results in Table 5. Trend inflation is negatively significant and inflation uncertainty is positively significant. Hence, both trend inflation and inflation uncertainty seem to predict RPD.

Table 5: UK GARCH-M GRIER

					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***)

4.4.4 US - General Model - VARMA(1,4) Bivariate GARCH-M

The results in Table 6 show that inflation affects RPD significanly and the sign of the effect is positive. In constrast, 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.

The specification tests for US reveal that the chosen model is well specified. All nested models tested (see Table 8) are rejected.

Table 6: US - AR=1 MA=4 GARCH(1,1)-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 not reported here. RPD_t = RPD ; RPD_{t-1} = RPD LAG; π_t = Inflation; π_{t-1} = Inflation Lag; $\sqrt{h_{rpd,t}}$ = Standard deviation of RPD; $\sqrt{h_{\pi,t}}$ = Standard deviation of Inflation. The first error lags for inflation mean equation are highly significant. Only 2nd, 3rd and 4th inflation error lags and 4th RPD error lag are significant at 10%. t-statistics are in parentheses.

5 Conclusion

In this paper, we use a VARMA bivariate 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, only for ths US there is evidence for the menu cost models. 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 infltion 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 dat 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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Table 7: Initial Regressions for UK and US: the dependent variable is RPD

UK	(1)	(2)	(3)
	(b/t)	(b/t)	(b/t)
INFSQ	2.56		
	(12.58)		
INFSQLAG		1.13	-0.13
		(4.39)	(-0.41)
RPDLAG			0.83
			(12.23)
RPDMA			-0.51
			(-4.24)
CONST	113.60	145.50	176.7
	(9.74)	(9.87)	(4.78)
US	**(1)**	**(2)**	**(3)**
	(b/t)	(b/t)	(b/t)
INFSQ	2.92		
	(4.92)		
INFSQLAG		1.79	1.46
		(4.92)	(3.82)
RPDLAG			0.94
			(50.94)
RPDMA			-0.94
			(-27.16)
CONST	699	809	816
	(9.76)	(10.64)	(3.99)

Notes: Regressions (1) and (2) are standard traditional models and regression (3) is an ARMA model. t-statistics are in parentheses.

Table 8: UK - Specification Tests - 65 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(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	$H_0 = \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{12} = 0$	0.00	Chisq(6)=106.06

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

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

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

Table 9: UK - Specification Tests - 24 Sectors

NULL	TEST	Significance Level	Chisq
Diagonal VARMA	$\text{H}_0 = \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	0.00	Chisq(4)=37
No GARCH	$\text{H}_0 = \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ for all i and j	0.00	Chisq(12)=2017
No GARCH-M	$\text{H}_0 = \Psi_{ij} = 0$ for all i and j	0.00	Chisq(4)=45
No Asymmetry	$\text{H}_0 = \delta_{ij} = 0$ for all i and j	0.00	Chisq(4)=22
Diagonal GARCH	$\text{H}_0 = \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{12} = 0$	0.00	Chisq(6)=237

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

$$A = \begin{bmatrix} 0.608^{***} & 0.002 \\ (10.335) & (1.436) \\ 17.233^{***} & 0.520^{***} \\ (8.454) & (5.153) \end{bmatrix} \qquad B = \begin{bmatrix} 0.695^{***} & -0.007^{***} \\ (20.629) & (-7.518) \\ -0.746 & 0.186 \\ (-0.194) & (1,483) \end{bmatrix}$$

$$D = \begin{bmatrix} 0.557^{***} & 0.017^{***} \\ (3.226) & (4.080) \\ -10.285 & -0.550^{***} \\ (-1.898) & (-2.291) \end{bmatrix} \qquad C = \begin{bmatrix} 21.390 & 1,912^{***} \\ (1.797) & (7.674) \\ 0 & -0.001 \\ & (-0.035) \end{bmatrix}$$

Table 10: US - Specification Tests

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(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	$H_0 = \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{12} = 0$	0.02	Chisq(6)=15

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

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

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

Table 11: 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

Notes: Index weights for UK PLLU is as of 2005. *includes Articles Of Straw And Plaiting Materials

Table 12: 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 nes	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 nes		
5	**Chemicals and related products nes**	**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 nes	0.86	
6	**Manufactured goods classified chiefly by material**	**14.9**	**POLB,POLE, POLH,POLI,POLK,POLJ**
61	Leather; leather manufactures nes; dressed furskins	1.66	
62	Rubber manufactures nes	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 nes	1.66	POLI
67	Iron , steel	1.66	
68	Non-ferrous metals	1.66	POLK
69	Manufactures of metals nes	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 nes , parts nes	2.36	
75	Office machines , automatic data processing machines	2.36	POLM
76	Telecommunications , sound equipment	2.36	POLO
77	Electrical machinery, apparatus , appliances nes , 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**

Table Continued

SITC	Sectors	Weights	PPIW Codes UK
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 nes	1.06	
88	Photographic apparatus; optical goods; watches clocks	1.06	POLP
89	Miscellaneous manufactured articles nes	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**	

End of Table

Notes All SITC Codes, Sector Names and Index Weights of PLLU