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Industry Structure and the Dynamics of Price Adjustment

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Abstract

Using annual US data for gross domestic product originating by sector between 1947 and 1997 it is shown that a negative long-run relationship between inflation and the markup is present across the sectors as well as in the aggregate. A preliminary explanation based on industry structure is explored for the relative sizes of the impact of inflation on the markup in the long-run for the various sectors.

Keywords: Inflation, Wages, Prices, Markup, Competition, Industry Structure.
JEL Classification: C32, C52, E24, D40, E30

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CONTENTS

1. INTRODUCTION

Banerjee, Cockerell and Russell (1998) and Banerjee and Russell (2000a, 2000b) examine the proposition that there exists a negative long-run relationship in the Engle and Granger (1987) sense between the markup of price on unit costs and inflation.[1] The papers raise two important issues. First, are the results simply due to the use of aggregate macroeconomic data? And second, if the results are valid, do industry structure and the level of competition affect the estimated long-run relationship between inflation and the markup?

The investigation of the influence of industry structure on the cyclical behaviour of the markup has a long history in the empirical industrial organisation literature, starting with the papers by Domowitz, Hubbard and Petersen (1986, 1987, 1988) and discussed most recently by Rotemberg and Woodford (1999) and Simon (1999). These papers take no account of either the possibility that the markup may be an integrated series or that it bears a relation to inflation. We have argued elsewhere (see, for example, Banerjee and Russell (2000b)) that regardless of whether one considers the markup of prices over marginal cost or over unit costs, the negative relationship between the markup and inflation is important and easily identifiable from the data. The robustness of this result is also evident from noting that it does not make any difference whether the markup is approximated as the inverse of the labour share or constructed under parametric assumptions on the production function and steady state values for the markup, following Hall (1988).

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1 We find that the levels of prices and costs are best described as I(2) processes and that except for Japan they cointegrate to the markup. In each case the markup is shown to polynomially cointegrate with inflation which is interpreted as a long-run relationship between the variables and that relatively high inflation is associated with a relatively low markup and *vice versa*.

This paper therefore considers both the above issues. First we estimate the long-run relationship between the markup on unit labour costs and price inflation for the US economy using aggregate data and then for each of the broad sectors and sub-sectors using annual gross product originating (GPO) by industry data for the period 1947-1997. Using the aggregate database we re-establish the general finding of a negative long-run relationship between the markup and inflation for the United States. Furthermore, we find that in each sector where inflation and the markup are I(1) the long-run relationship reappears. The second issue is then addressed by comparing the inflation cost estimates with the associated levels of competition in these sectors.

Before turning to the empirical estimation in Section 3 we first consider briefly why inflation may impact on the markup. Section 4 considers how competition affects the long-run relationship between inflation and the markup.

2. EXPLAINING THE IMPACT OF INFLATION ON THE MARKUP

Explanations of the impact of inflation on the markup have focused on three separate pricing assumptions of firms; namely price-taking, non-colluding price-setting and colluding price-setting. Bénabou (1992) assumes price-taking firms where higher inflation leads to greater search in customer markets that increases competition and reduces the markup. Russell, Evans and Preston (1997) and Chen and Russell (1998) argue within a non-colluding price-setting model that firms are uncertain about the profit maximising price and face difficulties coordinating price changes in an inflationary environment.[2] They conclude that the coordination difficulties increase with inflation leading to a lower markup. Finally, Athey, Bagwell and Sanichiro (1998) and Simon (1999) assume

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2 A number of authors argue that firms find it difficult to coordinate price changes. For example, see Ball and Romer (1991), Eckstein and Fromm (1968), Blinder (1990), and Chatterjee and Cooper (1989).

colluding price-setting firms and argue that higher inflation and the associated higher variance of cost shocks makes it more difficult for firms to maintain collusive arrangements and this leads to greater competition and a lower markup.

An important aspect of all these theories is whether the relationships that they describe are of a long-run nature. For the models described by Bénabou (1992), Athey *et al*. (1998) and Simon (1999), the relationship will persist in the long-run if the variance of price and cost shocks increase with inflation, leading to greater search or difficulty in coordinating price changes among colluding firms. Alternatively, Russell *et al.* (1997) and Chen and Russell (1998) argue that a negative long-run relationship exists if uncertainty persists in the long-run. In a price-taking world, firms simply need to predict the profit maximising price so that they can set the profit maximising level of output. In the long-run, firms can identify the profit maximising price with certainty and so uncertainty disappears. However, with price-setting firms in an inflationary environment it is unlikely that the uncertainty will disappear if the source of the uncertainty is the inability to coordinate price changes. Furthermore, it is likely that uncertainty will increase with inflation as the frequency and / or size of the price changes in real terms increase.

3. GPO SECTOR ESTIMATES OF THE LONG-RUN RELATIONSHIP

This section estimates the long-run relationship between inflation, Δp, and the markup of price on unit labour costs, mu, using the now familiar I(1) techniques developed by Johansen (1988, 1995). It is proposed that in the long-run firms desire a constant markup of price on unit costs net of the cost of inflation. Following Banerjee *et al.* (1998) and Banerjee and Russell (2000a) we write the long-run relationship:

$$mu = q - l\,\Delta p \qquad (1)$$

where q, is the 'gross' markup and l is a positive parameter and termed the inflation cost coefficient.[3] Lower case variables are in logarithms and Δ is the change in the variable. The long-run relationship can be derived from an 'inflation cost' Layard / Nickell imperfect competition model of the markup where inflation imposes costs on firms.[4] In the standard model $l = 0$ and inflation imposes no costs on firms in the form of a lower markup net of the cost of inflation. In the more general model, $l > 0$ and the markup net of the cost of inflation falls with increasing inflation in the long-run.

The theoretical derivation of (1) and a detailed discussion of empirical models relating the markup with inflation are considered in Banerjee *et al.* (1998) and Banerjee and Russell (2000a). On an empirical level (1) can be interpreted as a particular I(1) reduction of the polynomially cointegrating relationship of an I(2) system. In this case prices and costs are I(2) and cointegrate to the markup and the markup in turn polynomially cointegrates with the differences of prices and costs. Under the assumption of linear homogeneity we can write the long-run relationship (1) as a function of the markup and price inflation alone.

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3 We would normally condition the long-run analysis on a stationary business cycle variable which would enable us to examine the short-run relationship between markup and the business cycle. However, the only available business cycle variables for the each sector is de-trended constant price GDP. Its use has two difficulties. First the series appear I(1). Second, measurement errors in the national accounts are likely to appear simultaneously in the price and output series so as to offset each other. This implies that estimates of the relationship between prices and output would be contaminated by the presence of the common measurement error.

4 For the standard Layard / Nickell model see Layard, Nickell and Jackman (1991) or Carlin and Soskice (1990).

Over the sample that we investigate it is likely that the competitive environment and technology have changed leading to unmodelled shifts in the gross markup, thereby making it difficult to identify a stable long-run relationship between the variables.[5] To capture these shifts the estimation proceeds with the inclusion of a trend. Spike dummies are introduced where necessary to capture the short-run erratic behaviour of the cost and price data.

3.1 The Gross Product Originating by Industry Data

The price and markup data are derived from the November 1998 *Survey of Current Business* published by the United States Department of Commerce for the period 1947-1997. This source provides annual estimates of the industrial distribution of gross domestic product by sector. Prices are measured at factor cost and the markup is defined as prices divided by unit labour costs. Table 1 lists the breakdown of the sectors by the 1987 SIC codes.

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[5] There is a conflict between the requirement for a long enough span of data to estimate the relationship and the likelihood that the longer the data the greater the chance of breaks occurring. This is especially the case using annual data.

Table 1: Industry Classification and Integration Properties of the Data

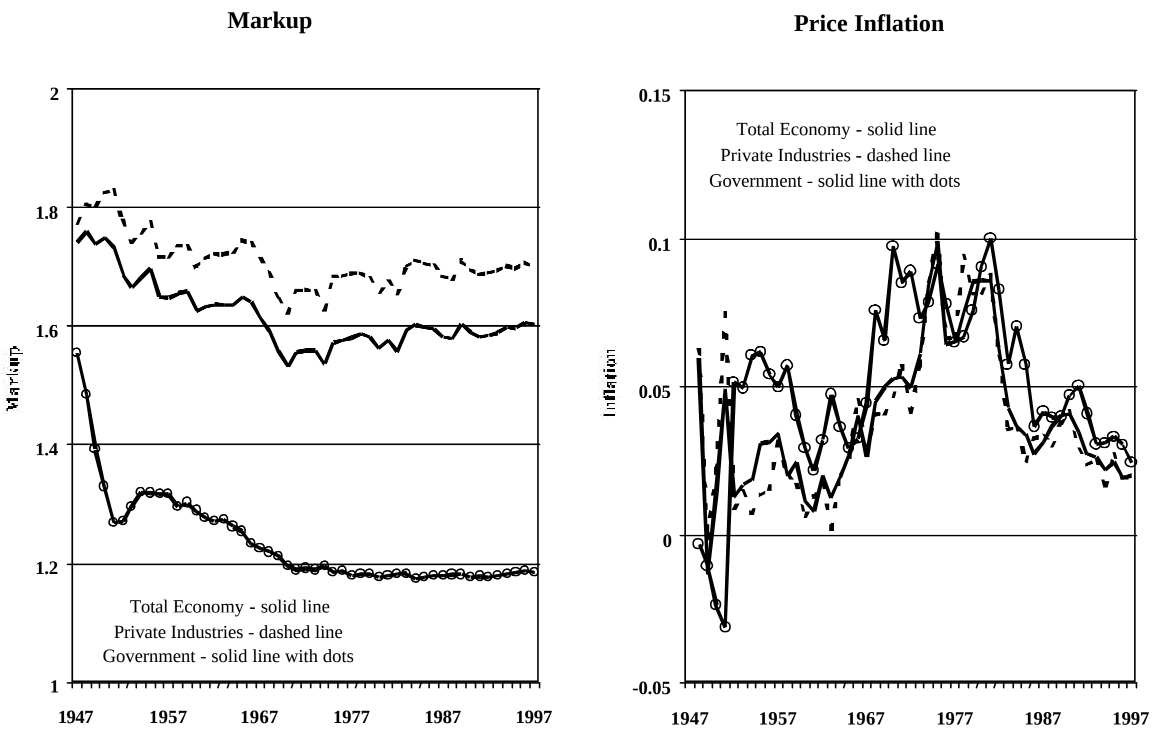
	Industry	*1987 SIC Code*	*Integration Properties*	
			Markup	*Inflation*
1	Total GDP	01-97	I(1)	I(1)[(b)]
2	Private Industries	01-42, 44-89	I(1)	I(1)[(b)]
3	Agriculture	01-09	I(1)	I(0)
4	Mining	10-14	I(1)	I(1)[(b)]
5	Construction	15-17	I(1)[(a)]	I(1)
6	Manufacturing	20-39	I(1)	I(1)[(b)]
7	Durable goods	24, 25, 32-39	I(1)	I(1)
8	Non-durable goods	20-23, 26-31	I(1)	I(0)
9	Transportation and public utilities	40, 42, 44-49	I(1)	I(1)
10	Transportation	40-42, 44-47	I(1)	I(1)
11	Communications	48	I(1)	I(1)[(b)]
12	Electricity, gas and sanitary services	49	I(1)	I(1)[(b)]
13	Wholesale trade	50-51	I(1)	I(0)
14	Retail trade	52-59	I(1)	I(1)[(b)]
15	Finance, insurance and real estate	60-67	I(1)	I(1)
16	Services	70-89	I(1)	I(1)
17	Government	43, 91-97	I(1)	I(1)

Notes: The univariate tests were undertaken for the sample 1947-1997 with the lag structure determined by AIC and BIC criteria. (a) indicates acceptance of both tests at the 1% level. (b) indicates acceptance of a unit root at the 5% level using the PT test and marginal rejection at the same level of significance using the DF-GLS test.

Graph 1 shows aggregate measures of the markup and annual inflation used in the estimation. The markup is the inverse of labour's income share. The graph reveals a steep decline in the markup for the economy as a whole and for private industries in general between 1947 and the mid-1960s. Several explanations for this decline present themselves. First, the relatively high markup may initially reflect the aftermath of the Second World War and Korean War when wages were constrained in the 'national interest' leading to a high markup.

Subsequently, the strong demand for labour following the wars pushed up real wages and the markup fell. A second explanation is that Japan, Germany and other European countries began to compete with the United States following reconstruction and led to a decline in the markup. A third explanation would focus on changes in the proportion of the self employed in the workforce.[6]

Graph 1: Total Economy, Private Industries and Government Sector



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6 If the proportion of self employed decreases then labour's income share rises and the markup on unit labour costs falls.

An unrestricted 'short trend' for the period 1947 –1966 is introduced to reflect these and other non-inflation influences on the markup.[7] The 'short trend' is significant in the aggregate estimates. Its appearance in the sector analysis is not uniform and indicates which sectors contribute to the decline in the aggregate markup.

Before estimating the system, the integration properties of the data were investigated using PT and DF-GLS univariate unit root tests from Elliot, Rothenberg and Stock (1996).[8] Table 1 shows the integration properties of the markup and prices for each of the sectors. The markup is clearly I(1). It appears that inflation is also I(1) for most of the sectors except agriculture, non-durable manufacturing and wholesale trade where inflation appears I(0).[9] The I(1) systems analysis that follows further supports these conclusions of the univariate unit root tests. We initially proceed assuming that the markup and inflation for all the sectors are I(1) and return to the issue of the order of integration for inflation following the estimation.

3.2 Results of the GPO Sector Analysis

Leaving aside the sectors where inflation appears I(0) from the univariate unit root tests, the hypothesis of one cointegrating vector is accepted and a significant negative relationships between inflation and the markup may be taken to exist in these sectors. Our findings are based not only upon a consideration of the Trace statistics reported in Appendix A (where for some sectors there is a marginal

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7 Following Doornik, Hendry and Nielsen (1998) in not restricting the 'short trend' dummy to lie in the cointegration space. A similar break in the long-run relationship is evident in the United States estimates reported in Banerjee and Russell (2000a).

8 These results are available on request from the authors.

9 One implication of finding the prices are I(2) and the markup is I(1) is that prices are cointegrating with unit labour costs to provide the markup and supports the formulation of the long-run equation (1).

rejection of the hypothesis of one cointegrating vector based on asymptotic critical values) but also upon looking at the roots of the companion matrix for the system. Under the maintained hypothesis of one cointegrating vector in a bivariate system with two I(1) variables the companion matrix has one root at unity and all other roots bounded away from unity. Our reasons for not relying solely on the critical values is that these are asymptotic and subject to finite sample distortions and sensitive to the presence of nuisance parameters such as constants, trends and spike or step dummies. If the critical values were to be recalculated for finite samples with the nuisance parameters taken into account, these are likely to be higher than the asymptotic critical values which would lead directly to more acceptances of one cointegrating vector.

The sectors for which the long-run relationship cannot be interpreted meaningfully (sectors 3, 8 and 13) are precisely those for which unit root testing leads us to conclude in favour of I(0) series for inflation. Consequently the question of a long-run relationship for these sectors cannot be answered. In these three sectors, if prices and the markup are I(1) this implies that prices and costs do not cointegrate to the markup as measured by the ratio of prices to unit labour costs. The roots of the companion matrix can no longer be interpreted as above since we no longer have a bivariate system of I(1) variables.

Table 2 shows the estimated adjustment coefficients and long-run relationships. The final column of this table reports the likelihood ratio test statistics and prob-values for the hypothesis that $l = 0$ where the cointegrating relationship may or may not have a significant trend term. Likelihood ratio tests for the latter are reported in Table 3 in the appendix along with the diagnostics for the systems on which the results are based.

Table 2: GPO Sector System Adjustment Coefficients and Cointegrating Vectors

	Sectors		*'Markup' Equation* Δmu	*Inflation Equation* $\Delta^2 p$	*Cointegrating Vector*	*Likelihood Ratio Test* $l=0$
1	Total GDP		- 0.412 (- 4.1)	- 0.332 (- 0.332)	$mu_t + 0.615\,\Delta p_t$	10.77 [0.00]
2	Private Industries		- 0.344 (- 3.5)	- 0.514 (- 4.5)	$mu_t + 0.603\,\Delta p_t$	13.21 [0.00]
3	Agriculture	*I(0) inflation*	- 0.002 (- 0.0)	0.358 (6.5)	$mu_t - 3.778\,\Delta p_t + 0.014T$	
4	Mining		- 0.030 (- 0.5)	- 0.338 (- 4.7)	$mu_t + 1.079\,\Delta p_t$	10.99 [0.00]
5	Construction		- 0.258 (- 3.4)	- 0.298 (- 2.3)	$mu_t + 0.663\,\Delta p_t$	5.84 [0.02]
6	Manufacturing		- 0.045 (- 1.1)	- 0.220 (- 4.8)	$mu_t + 2.780\,\Delta p_t$	19.17 [0.00]
7	Durable goods		- 0.101 (- 1.6)	- 0.190 (- 3.4)	$mu_t + 1.955\,\Delta p_t$	8.53 [0.00]
8	Non-durable goods	*I(0) inflation*	- 0.003 (- 0.8)	- 0.030 (-6.0)	$mu_t + 26.413\,\Delta p_t$	
9	Transportation and public utilities		- 0.014 (- 0.2)	- 0.441 (- 6.5)	$mu_t + 1.402\,\Delta p_t + 0.005\,T$	11.23 [0.00]
10	Transportation		- 0.022 (- 1.4)	- 0.111 (- 4.7)	$mu_t + 4.648\,\Delta p_t$	9.75 [0.00]
11	Communications		0.051 (0.9)	- 0.231 (- 6.5)	$mu_t + 5.243\,\Delta p_t - 0.010\,T$	26.33 [0.00]
12	Electricity, gas and sanitary services		0.040 (0.8)	- 0.320 (- 6.1)	$mu_t + 1.425\,\Delta p_t$	24.62 [0.00]
13	Wholesale trade	*I(0) inflation*	- 0.061 (- 1.1)	0.468 (5.6)	$mu_t - 1.790\,\Delta p_t$	
14	Retail trade		- 0.163 (- 2.0)	- 0.782 (- 9.1)	$mu_t + 0.982\,\Delta p_t + 0.004\,T$	36.99 [0.00]
15	Finance, insurance and real estate		- 0.004 (- 0.3)	- 0.082 (- 4.7)	$mu_t + 6.567\,\Delta p_t$	20.96 [0.00]
16	Services		- 0.158 (- 2.5)	- 0.348 (- 3.7)	$mu_t + 1.178\,\Delta p_t + 0.006\,T$	12.53 [0.00]
17	Government		- 0.328 (- 6.9)	- 0.702 (- 6.4)	$mu_t + 0.595\,\Delta p_t + 0.002\,T$	29.91 [0.00]

Notes: Estimation was for the period 1947-1997. Reported in ( ) are t-statistics. Normalised cointegrating vector reported after imposing 1 vector on the cointegration space. Likelihood ratio test distributed c_1^2 and reported in [ ] are prob-values. Initial estimation included two lags of the core variables, a trend restricted to the cointegrating space, and a 'short' trend for the years 1947-1966. The parsimonious form of the model was sort with the second lag of the core variable and the two trend variables eliminated when insignificant. Spike dummies were introduced for years with residuals greater than 3 standard errors. See the appendix for more details of the estimates of each sector.

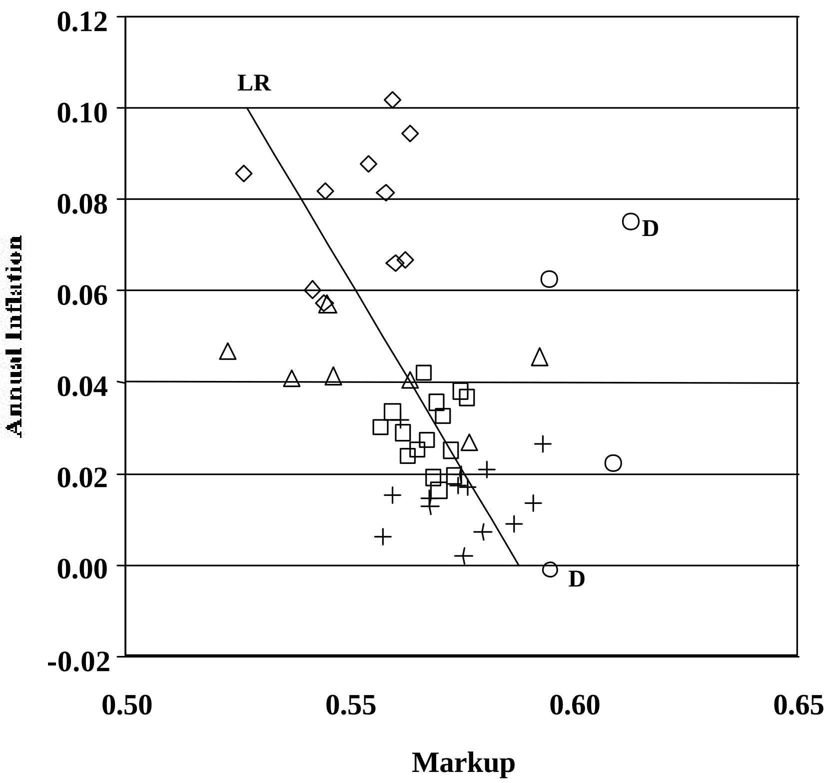
The long-run relationship estimated in Banerjee *et al.* (1998) and Banerjee and Russell (2000a, 2000b) re-emerges using the aggregate GDP and the aggregate private industry data. The coefficient estimate is very similar to those reported in Banerjee and Russell (2000a) for the United States once account is taken of the use of annual as opposed to quarterly data. The long-run relationship also appears strongly in the sectors providing the answer to the first question posed in the introduction, namely that the tradeoff between inflation and the markup is not only present in aggregate macroeconomic data but also appears in most of the sector data as well.

Graph 2 shows the actual realisations of inflation and the markup for the total of private industries as symbols where each represents a different 'inflationary episode'. Marked as 'D' are the observations corresponding to the spike dummies in the estimation. The inflationary episodes are defined below the graph. As we follow the inflationary episodes we see we move along the long-run curve, LR, with periods of relatively high inflation associated with relatively low markups.

The estimates for the inflation cost coefficient given by l vary between 0.663 for the construction sector and 5.243 for communications sector. These estimates are not necessarily directly comparable and their relative sizes should be interpreted with caution. For example, for the government sector, a large component of the finance sector, and a small component of the services sector prices are not market determined. To overcome the lack of market based price data the United States Department of Commerce effectively assumes constant productivity and the price index is equivalent to the wage index. Consequently the markup by definition is constant and fluctuations in the measured markup is due to minor 'non-price' influences such as capital depreciation charges. Furthermore, our underlying explanation of the long-run relationship rests on the assumption that firms set prices or operate in customer markets. In many industries these assumptions are not valid and the long-run relationship may appear for entirely different reasons such as price regulation, or very long price contracts such as those prevailing in the mining industry which leads to staggered price adjustment.

Graph 2

Private Industries - Inflation and the Markup



Inflationary Episodes
1948-51 – circle; 1952-65 – cross; 1966-71 – triangle; 1972-81 – diamond; 1982-97 - square

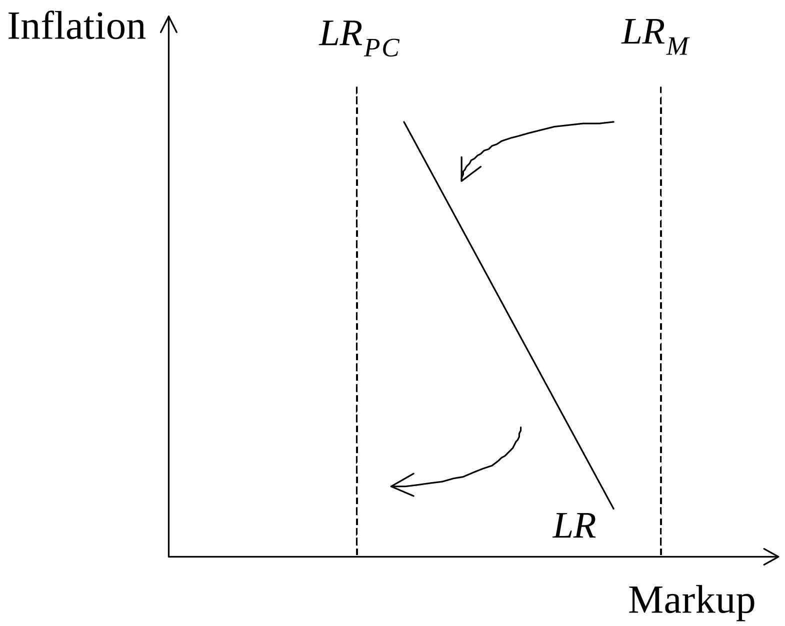
4. COMPETITION AND THE LONG-RUN RELATIONSHIP

While competition is a nebulous concept it is often argued that competition increases with the number of firms in an industry. The implication is that the economy better approximates the perfectly competitive case as the number of firms increase. A further implication is that there is a continuous spectrum of competitive states based on the number of firms from a monopoly with one firm to perfect competition with a large number of firms. Therefore, in a perfectly competitive price-taking world where there is no long-run relationship between inflation and the markup then $l = 0$ and the markup is dependent on 'real' factors alone. One might then conclude that increasing competition reduces the inflation cost coefficient l until in the limit of perfect competition $l = 0$.

However, this ignores the complications introduced by considering price-setting rather than price-taking firms and the source of the long-run relationship between the markup and inflation. Assuming that an increase in the number of firms leads to a closer approximation to perfect competition in a non-colluding price-setting world one must also assume that more firms not only reduces market power but simultaneously *reduces* uncertainty and the missing information concerning the coordination of price changes. While the former is likely to lead to a reduction in the level of the markup, the latter does not necessarily follow with price-setting firms. It is more likely that an increase in the number of firms leads to an increase in uncertainty because it is more difficult to coordinate price changes. Greater competition for price-setting firms, therefore, leads to an increase in uncertainty and a larger inflation coefficient, l.

Consequently we can consider two limiting cases as shown in Diagram 1. The first is where the long-run curve is vertical for perfectly competitive firms with $l = 0$ and labelled LR_{PC}. In the case of price-taking firms, increasing competition rotates the long-run curve, LR, in a clockwise direction while simultaneously lowering the mean value of the long-run markup for a given range of inflation.

Diagram 1: The Impact of Competition on the Long-Run Relationship



The second limiting case is for a monopoly. The theories outlined in Section 2 imply that inflation has no impact on the markup of a monopoly in the long-run.[10] In this case the inflation cost coefficient $l = 0$, the long-run curve is again vertical (labelled LR_M in Diagram 1) and the long-run markup is greater than in the perfectly competitive case.

In the case of a monopoly an increase in competition would see a reduction in the slope of the long-run curve as the long-run curve rotates in an anticlockwise direction and the mean value of the curve for a given range of inflation falls. If at some point firms behave as price-takers, increasing competition will no longer reduce the slope of the long-run curve and the slope will increases as the long-

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[10] This assumes that there is no other source of inflation related price uncertainty for a monopoly.

run curve rotates in a clockwise fashion. However, the mean value of the markup will continue to fall with increasing competition.

This discussion suggests two things. First, the size of the inflation coefficient depends in part on industry structure. Second, as one moves through the spectrum of competition from monopoly to perfect competition, at some point the relationship between competition and the inflation coefficient reverses and this point will depend on the technology and nature of the industry itself. Consequently there is no monotonic relationship between measures of competition and the inflation coefficient and the use of measures of competition to make comparisons across industries is difficult unless one controls for the pricing behaviour of these industries.[11]

Using our results this argument can be shown graphically. Graph 3 shows the relationship between the inflation coefficients from the GPO sector analysis and two measures of competition.[12] In the top panel the relationship is with a 'sales-weighted' 4-firm concentration ratio.[13] The lower panel shows the relationship between the inflation cost coefficient and an 'aggregate' Herfindahl Index.[14] In

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11 Geroski (1983) makes a similar point.

12 The data used to calculate the concentration ratios and Herfindahl Indexes are from the *1992 Economic Census Establishments and Firm Size* reports by the United States Census Bureau.

13 The 'sales weighted' 4-firm concentration ratio is a weighted sum of the two digit 4-firm concentration ratios in the sector where the weights are the share of sales in total sales in the sector. For a straightforward explanation of this calculation see Henley (1994).

14 Two steps are undertaken in producing the 'aggregate' Herfindahl Index. First, an approximate Herfindahl Index is calculated at the 2-digit level from the 4, 8, 20 and 50-firm concentration ratios. These indexes are real numbers and can be inverted, summed, divided by the number of 2-digit sectors and then inverted again. See Hay and Morris (1991) for further details of the Herfindahl Index.

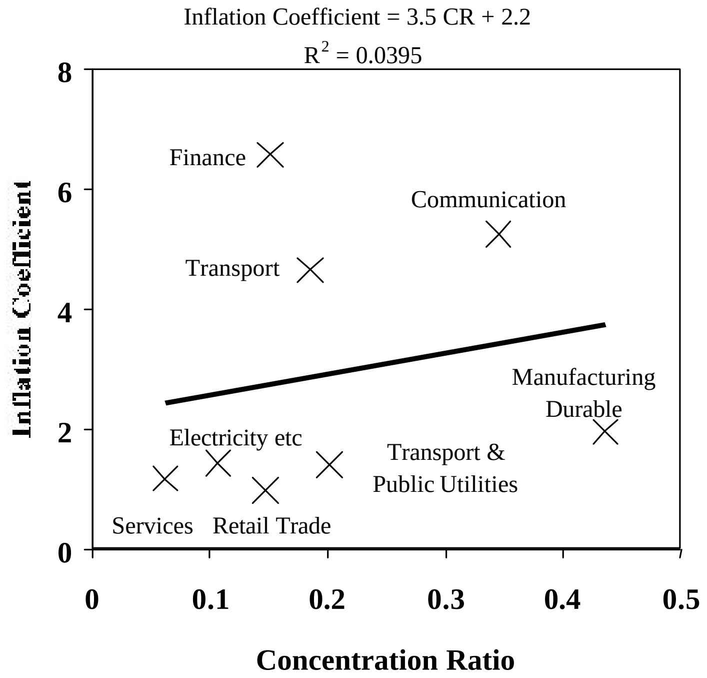
both these graphs the implication is that greater competition lowers the inflation coefficient. However, removing the finance observation due to the measurement problems associated with the data, and communications and durable manufacturing because of the very high levels of industry concentration (and therefore unlikely to have the same pricing behaviour as the other sectors) we see that there is largely no relationship between the inflation coefficient and competition. This is shown in Graph 3b.

5. CONCLUSION

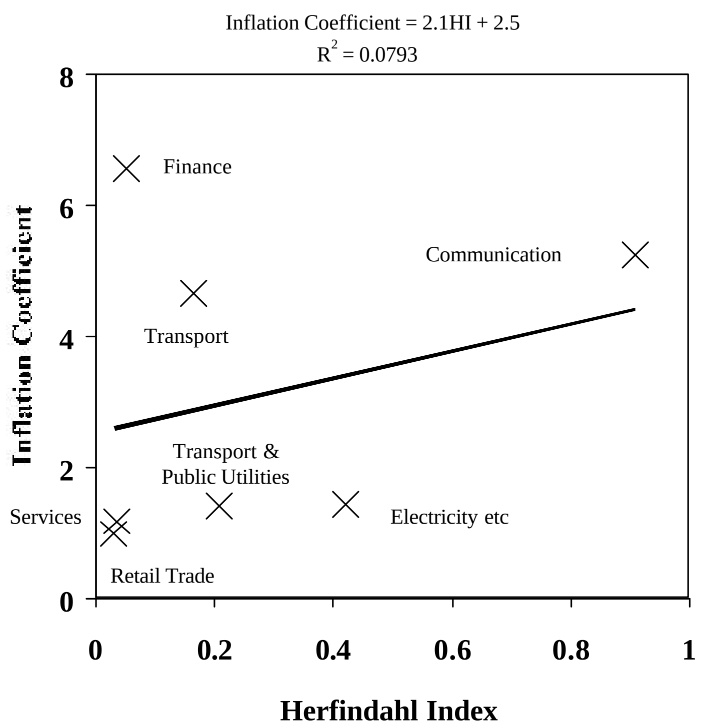
Using GPO data the finding of a long-run negative relationship between inflation and the markup is demonstrated for the aggregate United States economy and for twelve of the fifteen sectors. A clear relationship between the inflation cost coefficient and measures of competitiveness in the various sub-sectors is, however, not established. We argue that the relationship between competition and the inflation cost coefficient is not monotonic and therefore measures of competition and the inflation coefficient should not be related.

Graph 3: Measures of Competition and the Inflation Coefficient Gross Originating Product Data

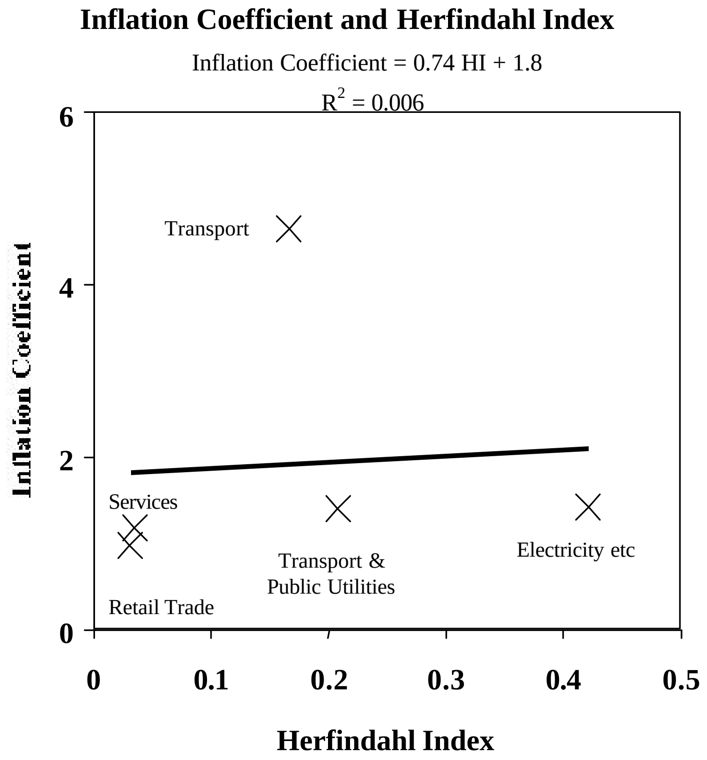
Inflation Coefficient and Sales-weighted 4- Firm Concentration Ratios



Inflation Coefficient and Herfindahl Index



Graph 3b: Measures of Competition and the Inflation Coefficient
Gross Originating Product Data



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APPENDIX: DETAILS OF THE GPO BY SECTOR I(1) ANALYSIS

Table A1: Testing for the Number of Cointegrating Vectors
Estimated Values of Q(r)

1 Total GDP

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.3426	25.42 {13.31}
1	0.0945	4.86 {2.71}

2 Private Industries

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.4173	32.78 {13.31}
1	0.1210	6.32 {2.71}

3 Agriculture

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.5265	41.53 {22.95}
1	0.1109	5.64 {10.56}

4 Mining

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.3635	21.97 {13.31}
1	0.0059	0.28 {2.71}

5 Construction

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.2854	22.51 {13.31}
1	0.1245	6.38 {2.71}

6 Manufacturing

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.3473	22.34 {13.31}
1	0.0289	1.44 {2.71}

7 Durable Goods

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.2494	18.50 {13.31}
1	0.0867	4.44 {2.71}

8 Non-durable Goods

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.4302	28.25 {13.31}
1	0.0139	0.69 {2.71}

9 Transportation & Public Utilities

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.4646	33.02 {22.95}
1	0.0479	2.41 {10.56}

10 Transportation

$H_0 : r =$	Eigenvalues	*Q*(*r*)
0	0.3233	28.45 {13.31}
1	0.1732	9.32 {2.71}

11 Communication

$H_0 : r =$	Eigenvalues	Q(r)
0	0.4826	36.85 {22.95}
1	0.1031	5.22 {10.56}

12 Electricity, Gas & Sanitary Services

$H_0 : r =$	Eigenvalues	Q(r)
0	0.4563	31.34 {13.31}
1	0.0298	1.48 {2.71}

13 Wholesale Trade

$H_0 : r =$	Eigenvalues	Q(r)
0	0.4897	40.65 {13.31}
1	0.1451	7.68 {2.71}

14 Retail Trade

$H_0 : r =$	Eigenvalues	Q(r)
0	0.6518	64.77 {13.31}
1	0.2342	13.08 {2.71}

15 Finance, insurance & real estate

$H_0 : r =$	Eigenvalues	Q(r)
0	0.3560	21.89 {13.31}
1	0.0067	0.33 {2.71}

16 Services

$H_0 : r =$	Eigenvalues	Q(r)
0	0.2903	21.08 {22.95}
1	0.0835	4.27 {10.56}

17 Government

$H_0 : r =$	Eigenvalues	Q(r)
0	0.7224	72.55 {22.95}
1	0.2053	11.03 {10.56}

Notes: Statistics are computed with 1 or 2 lags of the core variables (see Table A2). Reported are the test statistics of the final model reported in Table 2. *Q(r)* is the likelihood ratio statistic for determining *r* in the I(1) analysis. 90 percent critical values shown in curly brackets { } are from Table 15.3 and 15.4 of Johansen (1995) depending on whether or not a deterministic trend is included in the model.

Table A2: Modulus of the Roots of the Companion Matrix
($r = 1$ imposed)

		No of lags	1	2	*3*	4
1	Total GDP	1	1.0000	0.3836		
2	Private Industries	1	1.0000	0.3461		
3	Agriculture	2	1.0000	0.6238	0.6238	0.3558
4	Mining	2	1.0000	0.6370	0.3781	0.3781
5	Construction	2	1.0000	0.4559	0.4559	0.1250
6	Manufacturing	1	1.0000	0.3430		
7	Durable goods	1	1.0000	0.5268		
8	Non-durable goods	1	1.0000	0.2108		
9	Transportation and public utilities	1	1.0000	0.3684		
10	Transportation	1	1.0000	0.4605		
11	Communications	2	1.0000	0.4871	0.4871	0.3791
12	Electricity, gas and sanitary services	1	1.0000	0.5834		
13	Wholesale trade	1	1.0000	0.1010		
14	Retail trade	1	1.0000	0.0690		
15	Finance, insurance and real estate	1	1.0000	0.4688		
16	Services	1	1.0000	0.4313		
17	Government	2	1.0000	0.6582	0.6582	0.2239

Table A3: GPO I(1) System Analysis

1 Total GDP

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and 'spike' dummies for 1949 and 1951.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 0.70, p-value = 0.40, Inflation cost coefficient is zero c_1^2 = 10.77, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =5.05, p-value=0.28, LM(4) c_4^2 =0.75, p-value=0.94

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 1.42, p-value = 0.84

2 Private industries

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and 'spike' dummies for 1949 and 1951.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 0.46, p-value = 0.50, Inflation cost coefficient is zero c_1^2 = 13.21, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =1.67, p-value=0.80, LM(4) c_4^2 =3.68, p-value=0.45

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 3.91, p-value = 0.42

3 Agriculture

Number of observations: 48. Lags in the core variables = 2.

Predetermined variables:

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 4.29, p-value = 0.04, Inflation cost coefficient is zero c_1^2 = 29.68, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =2.87, p-value=0.58, LM(4) c_4^2 =3.06, p-value=0.55

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 6.41, p-value = 0.17

4 Mining

Number of observations: 48. Lags in the core variables = 2.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and 'spike' dummies for 1974 and 1986.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 0.06, p-value = 0.80, Inflation cost coefficient is zero c_1^2 = 10.99, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =4.45, p-value=0.35, LM(4) c_4^2 =2.24, p-value=0.69

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 10.57, p-value = 0.03

5 Construction

Number of observations: 48. Lags in the core variables = 2.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and ‘spike’ dummies for 1958 and 1983.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 3.46, p-value = 0.06, Inflation cost coefficient is zero c_1^2 = 5.84, p-value = 0.02

Tests for Serial Correlation: LM(1) c_4^2 =10.76, p-value=0.03, LM(4) c_4^2 =4.88, p-value=0.30

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 7.83, p-value = 0.10

6 Manufacturing

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables:

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 2.05, p-value = 0.15, Inflation cost coefficient is zero c_1^2 = 19.17, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =1.10, p-value=0.89, LM(4) c_4^2 =2.02, p-value=0.73

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 3.81, p-value = 0.43

7 Durable goods

Number of observations: 48. Lags in the core variables = 2.

Predetermined variables:

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 3.61, p-value = 0.06, Inflation cost coefficient is zero c_1^2 = 8.53, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =4.36, p-value=0.36, LM(4) c_4^2 =0.61, p-value=0.96

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 5.69, p-value = 0.22

8 Non-durable goods

Number of observations: 48. Lags in the core variables = 2.

Predetermined variables: short trend 1947-1966 not in the cointegrating space.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 3.01, p-value = 0.08, Inflation cost coefficient is zero c_1^2 = 26.06, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2 =6.34, p-value=0.18, LM(4) c_4^2 =4.96, p-value=0.29

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 11.66, p-value = 0.02

9 Transportation and public utilities

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and 'spike' dummies for 1983.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 11.23, p-value = 0.00, Inflation cost coefficient is zero c_1^2 = 27.46, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2=0.90, p-value=0.93, LM(4) c_4^2=7.50, p-value=0.11

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 1.65, p-value = 0.80

10 Transportation

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables:

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 0.01, p-value = 0.94, Inflation cost coefficient is zero c_1^2 = 9.75, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2=2.94, p-value=0.57, LM(4) c_4^2=5.13, p-value=0.27

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 1.14, p-value = 0.89

11 Communication

Number of observations: 48. Lags in the core variables = 2.

Predetermined variables:

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 17.25, p-value = 0.00, Inflation cost coefficient is zero c_1^2 = 26.33, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2=5.11, p-value=0.28, LM(4) c_4^2=3.59, p-value=0.46

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 3.14, p-value = 0.54

12 Electricity, gas and sanitary services

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and 'spike' dummies for 1973 and 1975.

Likelihood ratio tests: Trend in the cointegrating space is zero c_1^2 = 1.36, p-value = 0.24, Inflation cost coefficient is zero c_1^2 = 24.62, p-value = 0.00

Tests for Serial Correlation: LM(1) c_4^2=4.73, p-value=0.32, LM(4) c_4^2=9.79, p-value = 0.04

Test for Normality: Doornik-Hansen Test for normality c_4^2 = 10.38, p-value = 0.03

13 Wholesale trade

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space.

Likelihood ratio tests: Trend in the cointegrating space is zero c^2_1 = 0.76, p-value = 0.38, Inflation cost coefficient is zero c^2_1 = 25.26, p-value = 0.00

Tests for Serial Correlation: LM(1) c^2_4 =4.98, p-value=0.29, LM(4) c^2_4 =5.55, p-value = 0.24

Test for Normality: Doornik-Hansen Test for normality c^2_4 = 8.77, p-value = 0.07

14 Retail trade

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and 'spike' dummies for 1951, 1974 and 1987.

Likelihood ratio tests: Trend in the cointegrating space is zero c^2_1 = 31.54, p-value = 0.00, Inflation cost coefficient is zero c^2_1 = 36.99, p-value = 0.00

Tests for Serial Correlation: LM(1) c^2_4 =4.26, p-value=0.37, LM(4) c^2_4 =6.91, p-value=0.14

Test for Normality: Doornik-Hansen Test for normality c^2_4 = 2.08, p-value = 0.72

15 Finance, insurance and real estate

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables:

Likelihood ratio tests: Trend in the cointegrating space is zero c^2_1 = 2.37, p-value = 0.12, Inflation cost coefficient is zero c^2_1 = 20.96, p-value = 0.00

Tests for Serial Correlation: LM(1) c^2_4 =5.61, p-value=0.23, LM(4) c^2_4 =0.71, p-value =0.95

Test for Normality: Doornik-Hansen Test for normality c^2_4 = 2.16, p-value = 0.71

16 Services

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space.

Likelihood ratio tests: Trend in the cointegrating space is zero c^2_1 = 9.59, p-value = 0.00, Inflation cost coefficient is zero c^2_1 = 12.53, p-value = 0.00

Tests for Serial Correlation: LM(1) c^2_4 =8.11, p-value=0.09, LM(4) c^2_4 =4.43, p-value = 0.35

Test for Normality: Doornik-Hansen Test for normality c^2_4 = 3.40, p-value = 0.49

17 Government

Number of observations: 49. Lags in the core variables = 1.

Predetermined variables: short trend 1947-1966 not in the cointegrating space, and ‘spike’ dummies for 1951 and 1959.

Likelihood ratio tests: Trend in the cointegrating space is zero c^{2}_{1} = 33.82, p-value = 0.00, Inflation cost coefficient is zero c^{2}_{1} = 29.91, p-value = 0.00

Tests for Serial Correlation: LM(1) c^{2}_{4} =12.84, p-value=0.01, LM(4) c^{2}_{4} =3.02, p-value=0.55

Test for Normality: Doornik-Hansen Test for normality c^{2}_{4} = 1.39, p-value = 0.85