EUROPEAN UNIVERSITY INSTITUTE

DEPARTMENT OF ECONOMICS

EUI Working Paper **ECO** No. 2002/3

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Printed in Italy in January 2002
European University Institute
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AN OPTIMISING MODEL OF PRICE ADJUSTMENT WITH MISSING INFORMATION*

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20 December 2001

An optimising model of price adjustment with missing information is developed where firms choose the speed of price adjustment to minimise the expected loss in disequilibrium. The loss is due to lost profits and the expected cost of failing to coordinate price changes with competitors. Assuming that a higher speed of price adjustment decreases the former and increases the latter, it is shown that higher steady state inflation reduces the markup. This follows as the loss in profits increases with inflation and firms respond by increasing the speed of adjustment. However, the fear of coordination failure restricts the increase in the speed of adjustment and the markup falls.

Keywords: Menu Costs, Inflation, Markup, Price Adjustment, Disequilibrium
JEL Classification: D80, E10, E31

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* Both authors are at the Department of Economic Studies, University of Dundee. We would particularly like to thank Mike Artis, Hassan Molana and Michael Pollitt for their insightful comments and support. This paper is a revised version of Chen and Russell (1998). The gracious hospitality of the European University Institute, where the second author was a Jean Monnet Fellow while the paper was revised, is gratefully acknowledged. Correspondence: BRussell@Brolga.net.

CONTENTS

1. INTRODUCTION

This paper considers the proposition that nominal price inertia may lead to a negative relationship between inflation and the markup in the steady state for price setting firms.[1] The negative relationship has received increasing empirical support. Bénabou (1992), Simon (1999) and Batini, Jackson and Nickell (2000) identify a short-run negative relationship while Banerjee, Cockerell and Russell (2001), Banerjee and Russell (2000, 2001a, 2001b) and Banerjee, Mizen and Russell (2002) identify a negative long-run relationship in the Engle and Granger (1987) sense between inflation and the markup.[2]

A powerful explanation of the short-run relationship between inflation and the markup builds on the arguments of Mankiw (1985) and Parkin (1986) and focuses on the nominal price inertia due to small 'menu' costs.[3] Small *fixed* 'menu' costs slow price adjustment as firms adjust prices only after the benefit to do so outweigh the 'menu' cost associated with changing prices. Rotemberg (1983), Kuran (1986), Naish (1986), Danziger (1988), Konieczny (1990) and Bénabou and Konieczny (1994) show that the interaction of inflation and 'menu' costs may have real economic effects including variations in the average markup.[4]

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1 The steady state is defined as all nominal variables growing at the same constant rate.

2 Indirect support for the negative relationship is provided by the error correction models of inflation estimated by Richards and Stevens (1987), Franz and Gordon (1993), Cockerell and Russell (1995), and de Brouwer and Ericsson (1998). In these models the error correction term with linear homogeneity imposed can be interpreted as the markup and is negatively related with inflation.

3 Two further broad explanations of price inertia are noted. The first is based on the existence of long-term wage and price contracts as argued by Fischer (1977) and Phelps and Taylor (1977). The second includes work on 'kinked' demand curves by Sweezy (1939), Hall and Hitch (1939), Stigler (1947, 1978) and Maskin and Tirole (1988). However, both these broad explanations fail to explain the adjustment process and concentrate on the rigidity of wages and / or prices.

4 Barro (1972) models 'menu costs' with stochastic demand shocks. In the extensions to the model he raises, but does not pursue, the issue of trending price levels.

The 'menu' cost approach raises two important issues. First, it is unlikely that 'menu' cost models can explain a steady state relationship between inflation and the markup. These models assume that a fixed proportion of firms change their prices in each period. While this assumption is plausible for a given rate of steady state inflation it is likely to be unsustainable when the rate of steady state inflation changes. That is, higher steady state inflation would lead to a higher proportion of firms changing prices in each period as the cost of not adjusting prices with higher inflation increases substantially.[5] Furthermore, as argued by Batini, Jackson and Nickell (2000), the cost of adjusting prices is more likely to be a function of the deviation of price changes from the general (or steady state) rate of inflation rather than a function of the absolute change in prices. Consequently the relationship between inflation and the average markup generated by the 'menu' cost models is around given steady state values of inflation and the markup.

A more interesting issue is the nature of the 'menu' costs themselves. The focus in the literature following Mankiw (1985) and Parkin (1986) has been the actual real cost of price adjustment as characterised by the cost of the printing menus and price lists. A potentially far larger cost is the expected cost of failing to coordinate price changes between firms.[6] The cost of poor price coordination may be due to the loss of customers or 'price wars' and may lead to the failure of the firm in extreme cases. This characterisation of 'menu' costs suggests that they may be flexible rather than fixed and depend in part on the rate of inflation if coordination failure is a function of inflation. Furthermore, expected 'menu' costs may persist in the steady state if the fear of coordination failure persists.

The explanation of the negative relationship between inflation and the markup offered in this paper focuses on the nominal price inertia that results from the problems that firms face when coordinating price changes in a stable inflationary environment. In contrast with the fixed actual 'menu' cost literature, this paper may be interpreted as a flexible 'menu' cost model where 'menu' costs increase with the rate of inflation.

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5 See Sims (1988), Ball, Makiw and Romer (1988) and Dotsey, King and Wolman (1999).

6 A number of authors highlight the difficulty for firms to coordinate price changes. For example, see Ball and Romer (1991), Eckstein and Fromm (1968), Blinder (1990), and Chatterjee and Cooper (1989).

The model investigates the steady state relationship between the markup and inflation by considering the *routine* price setting behaviour of non-colluding firms in an uncertain inflationary environment. Firms on experiencing an increase in costs in an inflationary environment are aware that their competitors are experiencing similar increases in costs. The problem for the firm posed in this paper is to coordinate price increases with their competitors without colluding and thereby avoid the cost of poor price coordination.

Disequilibrium from the profit maximising markup imposes two forms of costs on the firm. First there is the lost profits when in disequilibrium. Second there is the expected cost of poor price coordination between firms as prices adjust back to the profit maximising markup. It is argued that firms in an uncertain economic environment will choose the speed that they adjust back to the profit maximising markup that minimises the expected loss while in disequilibrium. The expected loss is the sum of the lost profits in disequilibrium and the expected cost of coordination failure.

The speed of price adjustment impacts on the expected loss in two ways. The faster the speed of adjustment back to the profit maximising markup, the lower the adjustment cost in terms of lost profits. However, the faster the speed of adjustment the more likely the coordination failure between firms as they adjust prices. Therefore, a firm that is optimally choosing the speed of adjustment will increase the speed of adjustment until the marginal benefit to the firm in terms of lower adjustment costs just balances the marginal cost due to the increase in the expected cost of coordination failure. As might be expected, it is found that the speed of adjustment increases with the size of the disequilibrium from the desired price and falls with the cost of coordination failure. An important result is that unless the probability of coordination failure is insensitive to the speed of price adjustment then firms will adopt a 'gradualist' approach to price adjustment when in disequilibrium.[7] Consequently,

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[7] The assumption that underpins the 'gradualist' price adjustment is similar to the assumption of speed-dependent adjustment costs in the investment literature following Eisner and Strotz (1963) that leads to partial, or 'gradualist', adjustment behaviour by firms. However, note that in our paper the adjustment costs are the expected costs of adjustment.

the model displays nominal price inertia without the traditional ‘menu’ costs in the Mankiw and Parkin sense.

A ‘two stage’ modelling strategy is pursued in the next section. First, the source of the nominal price inertia is considered by analysing the firm’s pricing decision following a single shock to the markup. In the second stage the firm’s pricing behaviour in response to repeated shocks to the markup is analysed to investigate the steady state relationship between inflation and the markup. The repeated shocks are due to the firm operating in an inflationary environment. This ‘two stage’ modelling strategy simplifies the analysis allowing the paper to focus first on the source of the nominal price inertia before looking at the interaction of inflation and the price inertia.

The model predicts that higher steady state inflation leads to a lower markup unless the expected cost of coordination failure is insensitive to the speed of price adjustment. Higher inflation increases the cost of adjustment in terms of lost profits during disequilibrium and the firm responds by increasing the speed of price adjustment. However, while the increase in the speed of adjustment reduces the loss in profits it simultaneously increases the probability of coordination failure. Consequently the speed of adjustment does not increase by enough to maintain the level of the markup and the markup falls in the new steady state. The lower markup with higher inflation can be interpreted as the higher cost to firms of overcoming the missing information that may cause the failure to coordinate price changes.[8]

Before we turn to the model, we discuss an issue concerning methodology. There are two broad approaches to modelling the price setting behaviour of firms. The first assumes profit maximising firms, suitably differentiable production functions and the standard maximising solutions are sought. Given the nature of the problem examined here this approach is problematic as firms are in disequilibrium from the profit maximising markup while adjusting prices. Furthermore, if the firm’s production function is not suitably differentiable due to joint products of production then marginal costs may be undefined instead of simply

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[8] The increased expected cost of coordination failure with higher inflation is in a sense equivalent to an increase in ‘menu costs’ associated with adjusting prices.

being unknown. Consequently, firms may not set prices as a markup on marginal costs.[9] An alternative approach is to model the behaviour of firms directly. The predictions of the model can then be compared with the empirical evidence. The alternative approach is that followed here.

2. AN OPTIMISING MODEL OF PRICE ADJUSTMENT

This section sets out a model of how non-colluding price setting firm's routinely adjust prices when in disequilibrium from their desired profit maximising markup and when information concerning how to coordinate price changes is missing.[10] Firms operate in an inflationary environment where aggregate inflation is determined by the monetary authorities. Firms are not undertaking short-run strategic pricing policies and concern themselves only with the problem of coordinating changes in their prices when in disequilibrium.[11] The form of price coordination failure examined here is a non-synchronous change in prices between competing firms leading to unintended changes in the relative price of output between competitors.

Focussing on the routine price adjustment of firms allows a number of simplifying assumptions that make what is a complicated analysis tractable. The routine adjustment implies that shocks to the markup and real wage are not large enough to alter real decisions of the firm concerning the levels of output and employment as well as the level of investment and the capital stock. Consequently we can make the following simplifying assumptions.

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[9] There may be joint outputs of labour and non-labour inputs. For example, the joint products of a cow may be steak and hides. While there may be a set of profit maximising prices of the joint products there is no unique set of marginal costs. Consequently, firms cannot rely on marginal costs to set the profit maximising prices even though profit maximising prices exist. For the economics of joint products see Marshall (1920, 1927), Baumol (1976, 1977), Panzar and Willig (1977) and Willig (1979).

[10] Aspects of the model are considered in more detail in the mathematical appendix.

[11] While the short-run strategic pricing behaviour is ignored the threat of strategic behaviour remains in the steady state.

First, we assume an exogenous market structure and technology with no entry or exit of firms. The implications that follow from relaxing this assumption are considered in Section 4. Second, it is assumed that over the range of output associated with disequilibrium the firm experiences constant returns to scale. Third, the model is symmetrical in the sense that all firms are acting identically and with the same concerns for coordinating price changes. However, the symmetry does not imply that firms may assume that all other firms will behave identically to themselves and thereby solve the price coordination problem.

The firm holds a desired profit maximising markup of price on costs, π^*, and the disequilibrium is due to an *industry wide* exogenous increase in costs or an exogenous increase in the profit maximising price.[12] Characterising the shock to the markup in this way implies that when in disequilibrium the firm's markup is less than the desired markup. The model does not explain how the firm responds to *firm specific* cost increases although some indication of the firm's behaviour could be drawn from the model. Productivity is assumed constant and indexed to 1.

The firm's expected real loss in disequilibrium is the lost profits during the adjustment back to the desired markup which we refer to as the adjustment cost, A, and the loss to the firm in the event of failing to coordinate price changes, B.[13] The firm's expected loss function, $E(L)$, when in disequilibrium is written:

$$E(L) = A + \gamma B \tag{1}$$

where γ denotes the firm's subjective probability of coordination failure. The loss function is additive as the adjustment cost is incurred irrespective of whether coordination failure occurs.

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12 Alternatively, the analysis may be conducted in terms of the desired optimum markup if the profit maximising markup is not known.

13 Including 'menu costs' in the cost of adjustment complicates the exposition and does not affect the results of the model in an economic sense.

Given constant returns to scale and assuming labour is the only cost of production and an exogenous wage rate, W, we can represent the firm's lost profits in real terms during the adjustment as:

$$A = \int_0^\infty \pi^* \left(\frac{W\,L^*}{P_A} \right) - \pi_t \left(\frac{W\,L_t}{P_A} \right) dt \tag{2}$$

where P_A is the aggregate price level, L^* is the desired level of employment and π_t and L_t are the actual markup and labour employed at time t respectively. Equation (2) assumes there is no uncertainty concerning the future price of the firm's output as the firm is setting prices.

As mentioned above, this model concerns itself with the routine adjustment of prices in an inflationary environment and that the labour employed is independent of the exogenous increase in wages and, more importantly, the adjustment process while in disequilibrium. This may be due to hiring and firing costs and so firms do not adjust employment levels in response to what they perceive is a 'transitory' change in the markup and real wage when in disequilibrium.[14] Consequently, we replace the employment level, L_t, with the firm's desired or profit maximising value, L^*, and we can write (2) in the following form:

$$A = \int_0^\infty (\pi^* - \pi_t) C^* dt \tag{3}$$

where $C^* = WL^*/P_A$. For simplicity, assume that the markup follows a mean reversion process:

$$d\pi_t = \eta(\pi^* - \pi_t)\pi_t \; dt \tag{4}$$

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14 Recent studies show that hiring and firing costs may reduce employment fluctuations over the business cycle. For example see Bertola (1990, 1992), Bentolila and Bertola (1990), Booth (1995), Emerson (1988) and Nickel (1978, 1986).

where η is a positive parameter and represents the speed of adjustment back to the desired level of the markup and note that in an inflationary environment that $\pi^* \geq \pi_t$. Note also that $\eta(\pi^* - \pi_t)$ represents the percentage change in the markup as firms adjust prices.

In the 'real world', firms adjust prices in discrete intervals and decide on the frequency and size of the real change in prices. Therefore, we cannot simply measure the speed of adjustment in response to a cost shock in the 'real world' by either the frequency of price changes or the size of the change in price alone. Instead, the adjustment speed should be measured in terms of the loss in real profits during the disequilibrium. The faster the firm adjusts prices, the lower the loss in real profits irrespective of whether the faster adjustment is due to more frequent or larger price changes. The speed of adjustment parameter, η, in this model conforms to this conceptualisation of adjustment speed based on the loss in real profits. A higher value of η represents a faster speed of adjustment and results in a lower loss in real profits in disequilibrium.

Denoting the initial value of the markup, π_0, then the markup at time t is:

$$\pi_t = \frac{\pi^*}{1 + \left(\frac{\pi^*}{\pi_0} - 1\right) e^{-\pi^* \eta t}} \tag{5}$$

and the adjustment cost, A, can be written from (3), (4) and (5) as follows:[15]

$$A = \frac{\ln\left(\pi^*/\pi_0\right) C^*}{\eta}. \tag{6}$$

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[15] If we include a fixed 'menu' cost in the Mankiw and Parkin tradition this would alter the form of (6) slightly. Assuming that total menu costs in (3) can be represented by $\varphi M_C / \eta$, where φ is a parameter and M_C denotes menu cost then total menu costs decline with a higher adjustment speed. In this case (6) is: $A = \left(\ln\left(\pi^*/\pi_0\right) C^* + M_C \varphi\right)/\eta$. Therefore the impact of fixed 'menu costs' on the model is similar to that of C^* and for our purposes can be ignored.

Therefore, the adjustment cost depends on the speed of adjustment, η, and the percentage deviation of the markup from the desired markup, $\ln(\pi^*/\pi_0)$, scaled by the real costs of production, C^*.

Turning now to the expected real cost of coordination failure, γB. Coordination failure may occur in many ways and with various degrees of severity. The failure may lead to bankruptcy in severe cases or just lost customers and profits. For simplicity we assume that the cost of coordination failure can be represented by the constant B although we recognise that the term 'coordination failure' is an amalgam of a range of failures that may affect the firm's profits. It is also recognised that B may be a function of the speed of adjustment and the markup in a more complicated model.

Now suppose the probability of coordination failure increases with the speed of price adjustment due to firms trading in a customer market where frequent large changes in prices dislodge customers.[16] Alternatively, firms may believe that the larger the change in their prices (and therefore the faster the speed of price adjustment) the more obvious their price adjustment is to competitors in a given inflationary environment. Consequently, the faster the speed of price adjustment the greater the (subjective) probability of coordination failure because firms believe competitors are more likely to make strategic price changes when their own pricing behaviour is both more obvious and larger in real terms.

With no significant loss of generality, we can assume the following function for the probability of coordination failure, γ:

$$\gamma = \left(1 - \frac{1}{1 + (\alpha_0 - \alpha_1 \hat{y})\eta}\right), \quad (\alpha_0 - \alpha_1 \hat{y}) > 0 \tag{7}$$

[16] For the best conceptual outline of customer markets see Okun (1981). Alternatively, see McDonald and Spindler (1987), Bils (1989) and McDonald (1990).

where α_0 and α_1 are positive parameters.[17] The firm's trading conditions are represented by $\hat{y}$ and indexed such that $\hat{y}=0$ in the steady state and a positive value for $\hat{y}$ indicates that trading conditions are better than in the steady state. The parameter α_0 represents the sensitivity of the probability of coordination failure to the speed of adjustment for given trading conditions. The parameter is assumed to increase with competition of the form that leads to greater uncertainty concerning price coordination. However, trading conditions also influence the probability of coordination failure and this is represented by the parameter α_1.

Therefore, the firm's expected loss $E(L)$ when in disequilibrium from its desired markup is obtained by combining (1), (6) and (7) to give:

$$E(L) = \frac{\ln(\pi^*/\pi_0)C^*}{\eta} + \left(1 - \frac{1}{1 + (\alpha_0 - \alpha_1 \hat{y})\eta}\right)B. \tag{8}$$

The conundrum that faces the firm when adjusting prices in disequilibrium is revealed by (8). A higher speed of adjustment reduces the adjustment cost in terms of lost profits and $\ln(\pi^*/\pi_0)C^*/\eta$ is reduced. However, a higher speed of adjustment simultaneously increases the probability of coordination failure and the expected cost of coordination failure for given trading conditions, $\left(1 - \frac{1}{1 + (\alpha_0 - \alpha_1 \hat{y})\eta}\right)B$, increases. By increasing the speed of adjustment the firm incurs costs and benefits in terms of their expected profits. Therefore, an optimum speed of adjustment may exist that minimises the expected loss in disequilibrium.

2.1 A Single Shock to the Markup and the Optimum Speed of Price Adjustment

We now wish to use the model to consider the firm's response to a single shock to the markup. The firm chooses the optimum speed of adjustment back to the desired markup by

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[17] As $0 \le \gamma \le 1$, (7) satisfies the boundary conditions for a probability function.

selecting the speed of adjustment, η, that minimises the expected loss during the adjustment. Formally, this is achieved when $dE(L)/d\eta = 0$. From (8):

$$\frac{dE(L)}{d\eta} = -\frac{\ln(\pi^*/\pi_0)C^*}{\eta^2} + \frac{(\alpha_0 - \alpha_1\hat{y})B}{(1+(\alpha_0 - \alpha_1\hat{y})\eta)^2}. \tag{9}$$

Thus if $\eta = \hat{\eta}$ when $dE(L)/d\eta = 0$ then (9) gives the result:

$$\hat{\eta} = \frac{1}{\sqrt{\frac{(\alpha_0 - \alpha_1\hat{y})B}{\ln(\pi^*/\pi_0)C^*}} - (\alpha_0 - \alpha_1\hat{y})} \qquad if\ (\alpha_0 - \alpha_1\hat{y}) < \frac{B}{\ln(\pi^*/\pi_0)C^*} \tag{10}$$

Equation (10) indicates that the optimum speed of adjustment for the markup increases with the percentage deviation in the markup from its desired level, $\ln(\pi^*/\pi_0)$, and decreases with the cost of coordination failure, B. Assuming the cost of coordination failure is large and given the deviation from the desired markup small, we may assume that the satisfying condition is met.[18]

If the probability of coordination failure is independent of the adjustment speed then $\alpha_0 - \alpha_1\hat{y} = 0$ and thus $\hat{\eta} = \infty$. In this case the speed of adjustment has no impact on the cost of coordination failure and the firm minimises the expected loss by instantly adjusting back to the desired markup. However, in the more general case when $\alpha_0 - \alpha_1\hat{y} > 0$, then the greater the sensitivity of the probability of coordination failure to the speed of adjustment η, the slower the optimum speed of adjustment, $\hat{\eta}$. Therefore, firms that believe the probability of coordination failure is highly sensitive to the speed of adjustment will act more cautiously and adjust prices slowly leading to greater nominal price inertia.

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18 If B is small or if $\ln(\pi^*/\pi_0)$ is large and the satisfying condition is not met then there is no minimum of the expected loss function. In this case the firm will instantly increase the markup until $\ln(\pi^*/\pi_0)$ is small enough so the satisfying condition is met and the firm adjusts prices along the optimum path back to the profit maximising markup.

We can conclude, therefore, that unless the probability of coordination failure is unaffected by the speed of adjustment then the firm will follow a 'gradualist' approach to adjusting prices when in disequilibrium and not adjust instantaneously back to the desired markup.[19]

2.2 Inflation and the Markup in the Steady State

In section 2.1 we modelled the pricing behaviour of the firm in response to a single shock to the markup and found that concern for the failure to coordinate price changes leads to nominal price inertia. In this section we wish to extend the model to investigate the impact of this form of nominal price inertia on the firm's markup in an inflationary environment.

Assume that the firm is operating in an inflationary environment where the monetary authorities determine aggregate steady state inflation, $\overline{\Delta p}$, and that costs increase in line with steady state inflation.[20] In an inflationary environment the firm is repeatedly shocked away from its desired markup by exogenous increases in costs.

Conceptually, the firm might respond to an increase in costs in two ways. The first we term the immediate response. On experiencing the increase in costs, the firm increases prices immediately by some amount without concern for coordinating price changes with competitors. The immediate response is that associated with the satisfying condition of equation (10) not being met due to a large deviation in the markup from the profit maximisng markup (see footnote 16).

Following the immediate response, the markup may have fallen or, if the cost increase is fully passed through into higher prices, the markup will remain unchanged. If the markup falls below the profit maximising level then the firm's second response is to choose the optimum

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19 If the speed of adjustment has no impact on the expected cost of coordination failure then the cost of coordination failure is a 'fixed cost' and the firm minimises the loss in disequilibrium by adjusting instantaneously back to the desired markup.

20 The bar over a variable denotes its steady state value and Δ indicates the instantaneous percentage change. In this case $\Delta p = (1/p_t)(dp_t/dt)$.

speed of adjustment so as to minimise the expected loss in disequilibrium. The second response is that modelled in this paper and referred to as the disequilibrium response.

We can represent the impact of the immediate response on the markup in time *t* following an increase in costs as:

$$d\pi_t = \Delta uc\left(\psi - \pi_t\right)\pi_t \ dt \tag{11}$$

where Δuc is the percentage change in unit costs and ψ is a positive parameter and denoted the cost coefficient and $-1 \leq \psi - \pi_t \leq 0$.[21]

Two extreme values of ψ are relevant. If $\psi = \pi_t$ then the immediate response to an increase in costs is that prices are fully adjusted and the markup is unchanged. In this case, the markup is unaffected by an increase in costs even in the short-run and the disequilibrium response modelled here is not relevant. Alternatively, a rational firm would not *routinely* lower prices in response to an increase in unit costs and so the fall in the markup cannot be greater than the increase in costs as this implies that the price in the preceding period was not chosen 'optimally'. Therefore, $\psi - \pi_t \geq -1$ and $\psi \geq \pi_t - 1$.[22] Given that an increase in costs is usually associated with a fall in the markup in the short-run, it is likely that $\psi < \pi_t$ and the markup falls with an increase in costs.

In the steady state, costs increase in line with inflation and we can write (11) as:

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21 A more complicated model would incorporate the impact of trading conditions on the cost coefficient. For example, the cost coefficient may increase with trading conditions such that: $\psi = \psi_0 + \psi_1 \hat{y}$. However, in the steady state $\hat{y} = 0$ and the more complicated model collapses to (11).

22 Another value of the cost coefficient that is of interest is when $\psi = \pi_t - 1 + 1/\pi_t$ and $\psi - \pi_t = 1/\pi_t - 1$ in (11). In this case the firm increases prices to maintain nominal profits and consequently the markup falls. This is similar to the 'nominal cost hypothesis' in Russell (1998).

$$d\pi_t = \overline{\Delta p}\left(\psi - \pi_t\right)\pi_t \; dt \, . \tag{12}$$

Assuming steady state trading conditions where $\hat{y} = 0$ and that firms are choosing the optimum adjustment speed, $\hat{\eta}$, then combining (4) and (12), the steady state markup, $\overline{\pi}$, is:[23]

$$\overline{\pi} = \frac{\hat{\eta}\,\pi^* + \psi\,\overline{\Delta p}}{\hat{\eta} + \overline{\Delta p}} \, . \tag{13}$$

Rearranging (13) to highlight the impact of inflation on the steady state markup:

$$\overline{\pi} = \pi^* - \frac{\overline{\Delta p}\left(\pi^* - \psi\right)}{\hat{\eta} + \overline{\Delta p}} \leq \pi^* \tag{14}$$

or equivalently:

$$\overline{\pi} = \psi + \frac{\hat{\eta}\left(\pi^* - \psi\right)}{\hat{\eta} + \overline{\Delta p}} > \psi \, . \tag{15}$$

We see that higher steady state inflation reduces the markup relative to the profit maximising markup, π^*, and that as steady state inflation tends to an infinite rate the markup converges on ψ from above.

Finally, the expression for the steady state markup (13) is a function of the optimum speed of adjustment. Solving (10) and (13) simultaneously provides expressions for the markup and the speed of adjustment in the steady state in terms of the exogenous variables and parameters in the model.[24] The functional forms of the solution are complex and are reported in the Mathematical Appendix. Table 1 reports the sign of the impact of the exogenous terms

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[23] Combining (4) and (12) provides: $d\pi_t = \left(\hat{\eta}\pi^* + \overline{\Delta p}\,\psi - \left(\hat{\eta} + \Delta p\right)\pi_t\right)\pi_t \, dt$. In the steady state $d\pi_t = 0$ which gives equation (13).

[24] Defining the steady state as $\hat{y} = 0$ and $\overline{\pi} = \pi_0$.

on the markup, the speed of adjustment and the probability of coordination failure in the steady state.

Table 1: The Impact of the Exogenous Terms on the Markup, Speed of Adjustment, and the Probability of Coordination Failure in the Steady State

	Markup $\bar{\pi}$	Speed of Adjustment $\bar{\hat{\eta}}$	Probability of Coordination Failure $\bar{\gamma}$
Steady State Inflation $\overline{\Delta p}$	–	+	+
Real Cost of Coordination Failure B	–	–	–
Total Real Value of Production C^*	+	+	+
Cost Coefficient ψ	+ $\left(if\ \overline{\Delta p} > 0\right)$	– $\left(if\ \overline{\Delta p} > 0\right)$	–
Probability of Coordination Failure Coefficient α_0	–*	–**	+

* Assuming that $\alpha_0\, \hat{\eta} < 1$. ** Assuming that $\alpha_0 < B / \left[4 \ln\left(\pi^* / \bar{\pi}\right) C^*\right]$.

In the first row we see that an increase in the steady state rate of inflation reduces the markup while simultaneously increasing the speed of adjustment and the subjective probability of coordination failure. In this case, higher inflation initially leads to a fall in the markup due to the larger immediate response and, therefore, to a larger adjustment cost. Firms respond to the larger adjustment cost by increasing the speed of adjustment which in turn increases the probability of coordination failure and the expected cost of coordination failure. To offset some of the increase in the expected cost of coordination failure the firm does not increase the speed of adjustment by enough to maintain the steady state markup and the markup is lower with the 'new' steady state rate of inflation. Higher inflation, therefore, leads to a lower markup and the firm perceives a more hostile economic environment as reflected by the higher subjective probability of coordination failure. However, in the steady state the firm is unable to adjust directly to the profit maximising markup, π^*, due to the fear of failing to coordinate price changes with competitors.

The distinction should be made between the profit maximising markup, π^*, and the steady state markup, $\bar{\pi}$. The former is the markup desired by firms in the absence of the threat of coordination failure that is modelled here. The latter is the desired markup of firms subject to the constraint of the uncertainty introduced by the missing information that leads to the problems in coordinating price changes.

The second row of Table 1 reports the impact of increasing the cost of coordination failure where a higher value of B reduces the markup, the speed of adjustment and the probability of coordination failure. The higher cost of coordination failure increases the marginal cost of coordination failure and so firms respond by reducing the speed of adjustment which lowers the markup. The converse occurs with an increase in the real value of production, $C*$.

An increase in the cost coefficient ψ implies the immediate price response is greater and an increase in costs has less of a negative impact on the markup. The smaller deviation from the desired markup reduces the speed of adjustment. However, the fall in the speed of adjustment is less than that necessary to maintain the same level of the markup and the steady state markup rises.

Finally the coordination coefficient, α_0 has an ambiguous impact on the markup and the speed of adjustment in the steady state and is reported in the fifth row of Table 1. This is because an increase in α_0 increases the expected cost of coordination failure, γB, and this leads to a reduction in the speed of adjustment and the markup falls. The resulting increase in the percentage deviation from the desired markup causes the speed of adjustment to increase again offsetting some, or possibly all, of the initial fall in the speed of adjustment and the markup. Therefore, mathematically the sign on the total impact on $\overline{\pi}$ and $\overline{\hat{\eta}}$ of an increase in α_0 is indeterminate. However, assuming that the cost of coordination failure, B, is large and the deviation from the desired markup, $\ln(\pi*/\overline{\pi})$, is small then we can assume that the condition $\alpha_0 < B/\left[4\ln(\pi*/\overline{\pi})C*\right]$ is met and the speed of adjustment falls with an increase in α_0.[25] Therefore, as a reduction in the speed of adjustment unambiguously reduces the markup it follows that an increase in α_0 must also reduce the markup.[26]

3. ISSUES CONCERNING THE MODEL

3.1 Convergence to the Steady State

The percentage change in the markup at time *t* is the sum of the immediate and disequilibrium responses. Assuming that the firm optimally chooses the speed of adjustment and $\eta = \hat{\eta}$, then the change in the markup at time *t* can be written by combining (4) and (11):[27]

$$\Delta\pi_t = \underbrace{\Delta uc\left(\psi - \pi_t\right)}_{\text{Immediate Response}} + \underbrace{\hat{\eta}\left(\pi^* - \pi_t\right)}_{\text{Disequilibrium Response}} \tag{16}$$

Equation (16) reveals that in an inflationary environment there are two opposing forces operating on the markup. Unless $\psi = \pi_t$, the immediate response is a negative force serving to reduce the markup. There is also a positive force of the disequilibrium response as firms adjust back towards the desired markup. In the steady state when $\pi_t = \bar{\pi}$, $\hat{\eta} = \bar{\hat{\eta}}$ and $\hat{y} = 0$ the negative and positive forces are in balance and there is no change in the markup and $\Delta\pi_t = 0$. Alternatively, using the identity, $\Delta\pi_t \equiv \Delta p_t - \Delta uc_t$, we can rewrite (16) as an expression for inflation at time *t*:

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25 This result accords with common sense. If an increase in competition leads to an increase in the uncertainty surrounding the coordination of price changes then α_0 increases. It is reasonable, therefore, that firms act more cautiously with an increase in α_0 and the speed of adjustment slows.

26 This implies that the condition, $\alpha_0\,\hat{\eta} < 1$, in Table 1 must also be met.

27 The steady state markup (13) can be derived directly from (16) by setting $\Delta\pi_t = 0$ and $\Delta uc_t = \Delta p_t$.

$$\Delta p_t = \underbrace{\Delta uc\left(\psi - \pi_t + 1\right)}_{\text{Immediate Response}} + \underbrace{\hat{\eta}\left(\pi^* - \pi_t\right)}_{\text{Disequilbium Response}} . \qquad (17)$$

Again in the steady state when $\pi_t = \overline{\pi}$ and $\hat{\eta} = \overline{\hat{\eta}}$ we will find that $\Delta p_t = \Delta uc_t$.

Consider now the impact on inflation of an increase in unit costs when not in the steady state. When $\pi_t > \overline{\pi}$, and assuming that $\hat{y} = 0$, we find that the immediate and disequilibrium responses are both smaller than their steady state values. Therefore, inflation is less than the increase in costs and the markup falls when the markup is greater than its steady state value.[28] The converse holds if the markup is less than its steady state value.[29]

3.2 Price Adjustment in a Deflationary Environment

If firms are trading in a deflationary environment then the markup in disequilibrium is greater than the desired markup and $\pi_t > \pi^*$. Therefore, the cost of adjustment, A, in (6) is negative and firms do not adjust prices as the markup is greater than the desired level. Consequently, the model suggests that *routine* price adjustment of the type considered here is not compatible with a deflationary environment. This is consistent with the observation that prices appear to be 'sticky' downwards even in severe and protracted recessions when costs are declining. However, prices may fall out of the steady state in this model if the deflation in costs is due to poor trading conditions.

3.3 Actual Versus Expected Cost Increases

Two explanations can be provided for using actual and not expected changes in costs in the model. First, this assumption is consistent with the firm's fear of the threat of coordination failure. If firms were to change prices based on expected changes in costs then the firm is

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28 The immediate and disequilibrium responses are smaller than in the steady state as $\pi_t > \overline{\pi}$ in (17) and from (10) the lower markup implies that $\hat{\eta} < \overline{\hat{\eta}}$.

29 The conclusion that inflation is less than the increase in costs if the markup is above its steady state value must be qualified if trading conditions are not in the steady state.

exposed to relative price shifts and coordination failure as a result of mistaken cost expectations.

Second, firms have a greater incentive to use expected costs if there is some external constraint on the firm to fix the period between price changes. In the case where firms voluntarily set prices then responding to changes in actual costs eliminates the mistakes and the associated risks in setting the markup. The model is more relevant the greater the proportion of firms that are free to set prices. Casual observation indicates this is the majority of firms.

3.4 The Impact of Competition on the Steady State Relationship

While the concept of competition is nebulous the impact of competition on the steady state relationship between inflation and the markup is more straightforward. Competition affects the relationship through the sensitivity of the probability of coordination failure to the speed of adjustment, α_0, and the cost coefficient, ψ. If an increase in competition serves to increase the uncertainty surrounding the coordination of price changes then we can expect that α_0 will increase and ψ to decrease. Consequently the range in the steady state markup in an inflationary environment, $\pi^* - \psi$, increases.

3.5 The Impact of Entry and Exit on the Model

If firms are allowed to enter and exit the economy in response to changes in the steady state markup then the results of the model need to be modified but not overturned. Consider the case where monetary policy is tightened and the markup increases in the steady state due to the reduction in the rate of steady state inflation. If entry follows from the increase in the markup then this will add to the competitive environment serving to reduce the desired and steady state markup. However, given that the entry is due to a higher markup then entry alone cannot lead to the markup returning to its original level or else the incentive to enter disappears (and the marginal firms would leave the industry). If the markup did return to its original level following the entry of firms this implies there are two industrial structures associated with one level of the markup and suggests that the markup is independent competition and industrial structure. Therefore, to avoid this result the entry and exit of firms can only serve to reduce the negative steady state correlation between inflation and the markup and cannot eliminate the correlation.

4. CONCLUSION

In this paper we argue that the routine pricing behaviour of non-colluding price setting firms can be understood in the context of uncertainty concerning the coordination of price changes between competitors. As such there are two behavioural underpinnings employed in the model. The first is that firms believe that there is a cost associated with the failure to coordinate changes in prices. The second is that firms believe that the probability of coordination failure increases with the speed of price adjustment. These two underpinnings lead to nominal price inertia due to the ‘fear’ of price coordination failure.

As with the ‘menu’ cost models, it is shown that the markup is negatively related with inflation. However, unlike ‘menu’ cost models the underpinnings of the negative relationship do not disappear in the steady state as it is argued that the ‘fear’ of price coordination failure does not disappear in the steady state. Consequently the markup and inflation remain negatively related in the steady state.

It is crucial to this analysis that the missing information that underpins the threat of coordination failure remains missing in the steady state. In a perfectly competitive price taking world it is unlikely that uncertainty persists in the steady state. In this case firms simply need to predict the price level so as to set the profit maximising level of output. In the steady state the price level is predicted with certainty and uncertainty disappears.

However in the price setting world modelled here the uncertainty is of a different nature. Firms are uncertain of the pricing behaviour of their competitors and so coordinating price changes is difficult. While the model analyses the ‘routine’ adjustment of prices we argue that the pricing behaviour of firms is understood within the context of the threat of strategic price changes by competitors. Therefore, unless we assume that the threat of strategic price changes by competitors disappear in the steady state, the uncertainty and the negative relationship persists.

It is assumed that a firm in disequilibrium from its desired markup incurs two costs. The first cost is the lost profits while in disequilibrium. The second cost is due to the failure of firms to coordinate their price changes. The faster that firms return to their desired markup the smaller the lost profits in disequilibrium but the larger the expected cost of coordination failure. Firms that set their prices optimally when in disequilibrium will, therefore, choose the speed of adjustment to minimise the expected loss while in disequilibrium. It is found that the speed of adjustment increases with the deviation from the desired markup and falls with the cost of coordination failure. Furthermore, unless the probability of coordination failure is insensitive to the speed of adjustment, firms will follow a ‘gradualist’ approach to price adjustment when in disequilibrium from the desired markup leading to nominal price inertia.

If the firm was responding to only one shock to the markup then the markup would eventually return to its desired level. However, in an inflationary environment the firm will be repeatedly shocked away from its desired markup by increases in costs. In this case two ‘forces’ are acting on the markup. The first is the repeated increase in costs that drives the markup below its desired level. The second ‘force’ is the adjustment the firm makes to prices to return the markup back to its desired level. In the steady state these two ‘forces’ balance each other and there is no change in the markup. However, an increase in steady state cost inflation will drive the markup further away from its desired level. If the firm responded by sufficiently increasing the speed at which it adjusts back to the desired level of the markup then the steady state markup would be unchanged. However, the increase in the speed of adjustment is not sufficient as firms are concerned that the faster speed of price adjustment will increase the probability and expected cost of coordination failure. As a result the markup in the steady state falls with increasing inflation.

5. MATHEMATICAL APPENDIX

5.A Derivation of Equation 5

Rearranging (4) provides:

$$\left(\frac{1}{\pi_t - \pi^*} - \frac{1}{\pi_t}\right) d\pi_t = -\eta\,\pi^* dt\,. \tag{A1}$$

Integrating (A1) gives:

$$\frac{\pi^* - \pi_t}{\pi_t} = D_1\, e^{-\eta\,\pi^* t} \quad if\ \pi_t < \pi^*; \qquad \frac{\pi_t - \pi^*}{\pi_t} = D_2\, e^{-\eta\,\pi^* t} \quad if\ \pi_t > \pi^*\,. \tag{A2}$$

where D_1 and D_2 are unknown constants.

Constants D_1 and D_2 are determined by the initial condition. Setting t = 0 gives:

$$D_1 = \frac{\pi^*}{\pi_0} - 1;\ D_2 = 1 - \frac{\pi^*}{\pi_0}\,.$$

Substituting into (A2) gives equation (5) in the text.

5.B Derivation of Equation 6

Substituting (5) into (3) gives:

$$A = C^* \pi^* \int_0^{\infty} \left\{ 1 - 1 \big/ \left[1 + \left(\pi^* / \pi_0 - 1 \right) e^{-\pi^* \eta t} \right] \right\} dt\,. \tag{B1}$$

Let $Y = \left(\pi^* / \pi_0 - 1\right) e^{-\pi^* \eta t}$, so that:

$$dY = -\pi^* \eta Y dt\,. \tag{B2}$$

Substituting into (B1) gives

$$A=-\frac{C^*}{\eta}\int\left(\frac{1}{Y}-\frac{1}{Y(1+Y)}\right)dt=-\frac{C^*}{\eta}\int\left(\frac{1}{1+Y}\right)dt=-\frac{C^*}{\eta}\int d\ln(1+Y). \qquad \text{(B3)}$$

Thus:

$$A=-\frac{C^*}{\eta}\ln\left[1+\left(\frac{\pi^*}{\pi_0}-1\right)e^{-\pi^*\eta t}\right]\Bigg|_0^\infty=-\frac{C^*}{\eta}\left(0-\ln\left(\frac{\pi^*}{\pi_0}\right)\right)=\frac{C^*\ln\left(\frac{\pi^*}{\pi_0}\right)}{\eta}, \quad \text{(B4) = (6)}$$

5.C Derivation of Table 1

Rearranging (10) and (14) gives:

$$F\left(\overline{\Delta p},\pi^*,...,\overline{\pi}\left(\overline{\Delta p},\pi^*,...\right),\eta\left(\overline{\Delta p},\pi^*,...\right)\right)=\overline{\pi}\left(\hat{\eta}+\overline{\Delta p}\right)-\hat{\eta}\pi^*-\overline{\Delta p}\psi=0, \qquad \text{(C1)}$$

$$G\left(\overline{\Delta p},\pi^*,...,\overline{\pi}\left(\Delta p,\pi^*,...\right),\eta\left(\overline{\Delta p},\pi^*,...\right)\right)=\sqrt{\frac{\alpha_0 B}{C^*\ln\left(\pi^*/\overline{\pi}\right)}}-\hat{\eta}^{-1}-\alpha_0=0. \qquad \text{(C2)}$$

Note that in the steady state, $\hat{y}$ = 0 in (10).

Equations (C1) and (C2) are two functions, *F* & *G*, of six variables, $\overline{\Delta p}$, π^*, B, C^*, ψ, and α_0. We use the chain rule and Cramer's rule to differentiate $\overline{\pi}$ with respect to these six variables. Using the chain rule:

$$F_{\overline{\Delta p}}+F_{\overline{\pi}}\overline{\pi}_{\overline{\Delta p}}+F_{\hat{\eta}}\eta_{\overline{\Delta p}}=0 \qquad \text{(C3)}$$

$$G_{\overline{\Delta p}}+G_{\overline{\pi}}\overline{\pi}_{\overline{\Delta p}}+G_{\hat{\eta}}\eta_{\overline{\Delta p}}=0 \qquad \text{(C4)}$$

We can solve (C3) and (C4) for $\overline{\pi}_{\overline{\Delta p}}$ and $\hat{\eta}_{\overline{\Delta p}}$ by means of Cramer's rule. We get:

$$\bar{\pi}_{\overline{\Delta p}} = \frac{\begin{vmatrix} -F_{\overline{\Delta p}} & F_{\hat{\eta}} \\ -G_{\overline{\Delta p}} & G_{\hat{\eta}} \end{vmatrix}}{\begin{vmatrix} F_{\bar{\pi}} & F_{\hat{\eta}} \\ G_{\bar{\pi}} & G_{\hat{\eta}} \end{vmatrix}} \tag{C5}$$

$$\eta_{\overline{\Delta p}} = \frac{\begin{vmatrix} F_{\bar{\pi}} & -F_{\overline{\Delta p}} \\ G_{\bar{\pi}} & -G_{\overline{\Delta p}} \end{vmatrix}}{\begin{vmatrix} F_{\bar{\pi}} & F_{\hat{\eta}} \\ G_{\bar{\pi}} & G_{\hat{\eta}} \end{vmatrix}} \tag{C6}$$

We know that: $F_{\bar{\pi}} = \hat{\eta} + \overline{\Delta p}$, $G_{\bar{\pi}} = \frac{1}{2\bar{\pi}}\sqrt{\frac{\alpha_0 B}{C^*}}\left[\ln(\pi^*/\bar{\pi})\right]^{-1.5}$, $F_{\hat{\eta}} = \bar{\pi} - \pi^*$, $G_{\eta} = \hat{\eta}^{-2}$, and $F_{\overline{\Delta p}} = \bar{\pi} - \psi$, $G_{\overline{\Delta p}} = 0$. Thus:

$$\begin{vmatrix} F_{\bar{\pi}} & F_{\hat{\eta}} \\ G_{\bar{\pi}} & G_{\hat{\eta}} \end{vmatrix} = \frac{1}{\hat{\eta}} + \frac{\overline{\Delta p}}{\hat{\eta}^2} + \frac{(\pi^* - \bar{\pi})}{2\ln(\pi^*/\bar{\pi})}\sqrt{\frac{\alpha_0 B}{C^* \ln(\pi^*/\bar{\pi})}} = k > 0 \tag{C7}$$

$$\begin{vmatrix} -F_{\overline{\Delta p}} & F_{\hat{\eta}} \\ -G_{\overline{\Delta p}} & G_{\hat{\eta}} \end{vmatrix} = \begin{vmatrix} -(\bar{\pi} - \psi) & \bar{\pi} - \pi^* \\ -0 & \hat{\eta}^2 \end{vmatrix} = -(\bar{\pi} - \psi)\hat{\eta}^2 . \tag{C8}$$

Substituting (C7) and (C8) into (C5) gives:

$$\bar{\pi}_{\overline{\Delta p}} = \frac{-(\bar{\pi} - \psi)\eta^2}{k} < 0 . \tag{C9}$$

Similarly,

$$\overline{\pi}_{\pi^*} = \frac{\begin{vmatrix} -F_{\pi^*} & F_{\hat{\eta}} \\ -G_{\pi^*} & G_{\hat{\eta}} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} > 0\,; \quad \overline{\pi}_{B} = \frac{\begin{vmatrix} -F_{B} & F_{\hat{\eta}} \\ -G_{B} & G_{\hat{\eta}} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} < 0\,; \quad \overline{\pi}_{C^*} = \frac{\begin{vmatrix} -F_{C^*} & F_{\hat{\eta}} \\ -G_{C^*} & G_{\hat{\eta}} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} > 0\,;$$

$$\overline{\pi}_{\psi} = \frac{\begin{vmatrix} -F_{\psi} & F_{\hat{\eta}} \\ -G_{\psi} & G_{\hat{\eta}} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} > 0 \ \text{if} \ \overline{\Delta p} > 0\,; \quad \overline{\pi}_{\alpha_0} = \frac{\begin{vmatrix} -F_{\alpha_0} & F_{\hat{\eta}} \\ -G_{\alpha_0} & G_{\hat{\eta}} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} < 0 \ \text{if} \ \alpha_0\,\hat{\eta} < 1.$$

For the function of the adjustment speed, we can follow a similar process:

$$\hat{\eta}_{\overline{\Delta p}} = \frac{\begin{vmatrix} F_{\overline{\pi}} & -F_{\overline{\Delta p}} \\ G_{\overline{\pi}} & -G_{\overline{\Delta p}} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} > 0\,; \quad \eta_{\pi^*} = \frac{\begin{vmatrix} F_{\overline{\pi}} & -F_{\pi^*} \\ G_{\overline{\pi}} & -G_{\pi^*} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} > 0, \ \text{if} \ \overline{\Delta p} > \hat{\eta}\left(\frac{\pi^*}{\overline{\pi}} - 1\right); \quad \eta_{B} = \frac{\begin{vmatrix} F_{\overline{\pi}} & -F_{B} \\ G_{\overline{\pi}} & -G_{B} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} < 0\,,$$

$$\eta_{C^*} = \frac{\begin{vmatrix} F_{\overline{\pi}} & -F_{C^*} \\ G_{\overline{\pi}} & -G_{C^*} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} > 0\,; \quad \eta_{\psi} = \frac{\begin{vmatrix} F_{\overline{\pi}} & -F_{\psi} \\ G_{\overline{\pi}} & -G_{\psi} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} < 0 \ \text{if} \ \overline{\Delta p} > 0\,;$$

$$\eta_{\alpha_0} = \frac{\begin{vmatrix} F_{\overline{\pi}} & -F_{\alpha_0} \\ G_{\overline{\pi}} & -G_{\alpha_0} \end{vmatrix}}{\begin{vmatrix} F_{\overline{\pi}} & F_{\hat{\eta}} \\ G_{\overline{\pi}} & G_{\hat{\eta}} \end{vmatrix}} < 0 \ \text{if} \ \alpha_0 < B/\left[4\ln(\pi^*/\overline{\pi})C^*\right].$$

6. REFERENCES

Ball, L. and D. Romer (1991), 'Sticky Prices As Co-ordination Failure', American Economic Review, 81, pp. 539-552.

Ball, L., N.G. Mankiw, and D. Romer. (1988). 'The New Keynesian Economics and the Output-Inflation Trade-off.' (Brookings Papers on Economic Activity), pp. 1-65.

Banerjee, A., L. Cockerell, and B. Russell. (2001). 'An I(2) Analysis of Inflation and the Markup.' Journal of Applied Econometrics, 16 Sargan Special Issue:3 May-June, pp. 221-40.

Banerjee, A. and B. Russell. (2000). 'Markups and the Business Cycle Reconsidered.' European University Institute Working Paper, pp. ECO No. 2000/11.

Banerjee, A. and B. Russell. (2001a). 'Industry Structure and the Dynamics of Price Adjustment.' Applied Economics, 33:17, pp. 1889-901.

Banerjee, A. and B. Russell. (2001b). 'The Relationship between the Markup and Inflation in the G7 Economies and Australia.' Review of Economics and Statistics, 83:2 May, pp. 377-87.

Banerjee, A., P. Mizen and B. Russell. (2002). 'The Long-Run Relationships among Relative Price Variability, Inflation and the Markup.' European University Institute Working Paper, ECO No. 2002/1.

Barro, R. (1972). 'A Theory of Monopolistic Price Adjustment', The Review of Economic Studies, vol. 39, Issue 1, pp. 17-26.

Batini, N., B. Jackson, and S. Nickell. (2000). 'Inflation Dynamics and the Labour Share in the UK.' Bank of England External MPC Unit Discussion Paper:No. 2 November.

Baumol, W.J. (1976). 'Scale Economies, Average Cost and the Profitability of Marginal-Cost Pricing', in R. Grieson, ed., 'Essays in Urban Economics and Public Finance in Honor of William S. Vickrey, Lexington.

Baumol, W.J. (1977). 'On the Proper Cost Tests for Natural Monopoly in Multiproduct Industry', American Economic Review, December, 67, pp. 809-22.

Bénabou, R. (1992), 'Inflation and Markups: Theories and Evidence from the Retail Trade Sector', European Economic Review, 36, pp. 566-574.

Bénabou, R. and J.D. Konieczny. (1994). 'On Inflation and Output with Costly Price Changes: A Simple Unifying Result.' American Economic Review, 84:1 March, pp. 290-7.

Bentolila, S. and G. Bertola (1990), 'Firing Costs and Labor Demand: How Bad is Eurosclerosis?' Review of Economic Studies, 57, pp. 381-402

Bertola, G. (1990), ‘Job Security, Employment and Wages.’ European Economic Review, 34, pp. 851-86.

Bertola, G. (1992), ‘Labor Turnover Costs and Average Labor Demand’, Journal of Labor Economics, 10, pp. 389-411.

Bils, M. (1989), ‘Pricing in a Customer Market’, Quarterly Journal of Economics, 104, pp 699-718.

Blinder, A. S. (1990), ‘Why are Prices Sticky? Preliminary Results from an Interview Study’, AEA Papers and Proceedings, 81(2), pp. 89-96.

Booth, A. L. (1995), ‘The Employment Implications of State-Mandated Firing Costs.’ Working Paper of the ESRC Research Center on Micro-social Change No. 95-10, University of Essex.

Chatterjee, S. and R. Cooper (1989), ‘Economic Fluctuations as Co-ordination Failures: Multiplicity of Equilibria and Fluctuations in Dynamic Imperfectly Competitive Economics’, AEA Papers and Proceedings, 79(2), pp. 353-357.

Chen, Y. and B. Russell (1998). ‘A Profit Maximising Model of Disequilibrium Price Adjustment with Missing Information’, Department of Economic Studies Discussion Papers, No. 92, University of Dundee.

Cockerell, L. and B. Russell. (1995). ‘Australian Wage and Price Inflation: 1971-1994.’ Reserve Bank of Australia Discussion Paper:9509.

Danziger, L. (1988). ‘Costs of Price Adjustment and the Welfare Economics of Inflation and Disinflation.’ American Economic Review, 78:4 September, pp. 633-46.

de Brouwer, G. and N.R. Ericsson. (1998). ‘Modelling Inflation in Australia.’ Journal of Business and Statistics, 16, pp. 433-49.

Dotsey, M, R.G. King, and A.L. Wolman. (1999). ‘State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output.’ Quarterly Journal of Economics, 114:2, pp. 655-90.

Eckstein, O. and G. Fromm (1968), ‘The Price Equation’, American Economic Review, 58, pp. 1159-1183.

Eisner, R. and R. Strotz (1963), Impacts of Monetary Policy, Englewood Cliffs, New Jersey.

Emerson, M. (1988), ‘Regulation or Deregulation of the Labour Market.’ European Economic Review, 32, pp. 775-818.

Engle, R.F. and C. W. J. Granger. (1987). ‘Co-Integration and Error Correction: Representation, Estimation, and Testing.’ Econometrica, 55:March, pp. 251-76.

Fischer, S. (1977), ‘Long-term Contracts, Rational Expectations, and the Optimal Money Supply Rule’, Journal of Political Economy, 85, February, pp 191-205.

Franz, W. and R.J. Gordon. (1993). ‘German and American Wage and Price Dynamics: Differences and Common Themes.’ European Economic Review, 37, pp. 719-62.

Hall, R. L. and C. J. Hitch (1939), ‘Price Theory and Business Behaviour’, Oxford Economic Papers, 2 (old series) pp. 12-45.

Konieczny, J.D. (1990). ‘Inflation, Output and Labour Productivity when Prices are Changed Infrequently.’ Economica, 57:May, pp. 201-18.

Kuran, T. (1986). ‘Price Adjustment Costs, Anticipated Inflation, and Output.’ Quarterly Journal of Economics, 71:5 December, pp. 1020-7.

Mankiw, N. G. (1985), ‘Small Menu Costs and Large Business Cycles’, Quarterly Journal of Economics, 100, May, pp 529-39.

Marshall, A. (1920). Principles of Economics, London: MacMillan and Co.

Marshall, A. (1927). Industry and Trade, London: MacMillan and Co.

Maskin, E., and J. Tirole (1988), ‘A Theory of Dynamic Oligopoly 2: Price Competition, Kinked Demand Curves, and Edgeworth Cycles’, Econometrica, vol 56, (3), pp 571-99.

McDonald, I. M. (1990), Inflation and Unemployment, Oxford: Basil Blackwell

McDonald, I. M. and K. J. Spindler (1987), ‘An Empirical Investigation of Customer Market Analysis - A Microfoundation for Macroeconomics’, Applied Economics, 19.

Naish, H.F. (1986). ‘Price Adjustment Costs and the Output-Inflation Trade-Off.’ Econometica, 53, pp. 219-30.

Nickell, S. (1978), ‘Fixed Costs, Employment and labour Demand over the Cycle.’ Economica, 46, pp.329-45

Nickell, S. (1986), ‘Dynamic Models of Labor Demand.’ in Handbook of Labor Economics, Vol. 2. Edited by O. Ashenfelter and D. Layard. Amsterdam: North Holland.

Okun, A. M. (1981), Prices and Quantities: A Macroeconomic Analysis, Basil Blackwell, Oxford.

Panzar, J. and R.D. Willig (1977). ‘Economies of Scale in Multi-Output Production’, Quarterly Journal of Economics, August, 91, pp. 481-94.

Parkin, M. (1986), ‘The Output-Inflation Trade-off When Prices are Costly to Change’, Journal of Political Economy, 94, February, pp 200-24.

Phelps, E. S. and J. B. Taylor (1977), ‘Stabilizing Powers of Monetary Policy with Rational Expectations’, Journal of Political Economy, 85, February, pp 163-90.

Richards, T. and G. Stevens. (1987). 'Estimating the Inflationary Effects of Depreciation.' Reserve Bank of Australia Research Discussion Paper:8713.

Rotemberg, J.J. (1983). 'Aggregate Consequences of Fixed Costs of Price Adjustment.' American Economic Review, 73:June, pp. 433-6.

Russell, B. (1998). 'A Rules Based Model of Disequilibrium Price Adjustment with Missing Information.' University of Dundee Department of Economic Studies Discussion Paper:84 November.

Simon, J. (1999). 'Markups and Inflation.' Massachusetts Institute of Technology Mimeo.

Sims, C. (1988). 'Comments and Discussion.' Brookings Papers on Economic Activity, 1, pp. 75-79.

Stigler, G. J. (1947), 'The Kinked Oligopoly Demand Curve and Rigid Prices', The Journal of Political Economy, 55(5).

Stigler, G. J. (1978), 'The Literature of Economics: The Case of the Kinked Oligopoly Demand Curve', Economic Inquiry, vol 16, (2), pp. 185-204.

Sweezy, P. M. (1939), 'Demand Under Conditions of Oligopoly', Journal of Political Economy, 47 (4), pp. 568-73.

Willig, R.D. (1979). 'Multiproduct Technology and Market Structure', American Economic Review, May, 69, no. 2, pp. 346-51.