# A Rules Based Model of Price Adjustment*

Bill Russell

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**Abstract**

This paper sets out a 'rules based' model of price adjustment for non-colluding price setting firms. The model highlights the problems faced by firms when trying to coordinate price changes when information is missing and predicts that inflation and the markup will be negatively related in the steady state. The relationship is non-linear. At zero steady state inflation the markup is at a maximum and, as inflation increases, the markup declines to some minimum value. The lower markup with higher steady state inflation is interpreted as the cost to firms of overcoming the missing information when adjusting prices.

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## 1. INTRODUCTION

This paper considers the following question. How might firms adjust prices if firms do not know the path of the optimum (or profit maximising) price when operating in an inflationary environment and respond to this lack of knowledge by following a price rule? In particular, is there a general form of a price rule that is intuitively appealing in terms of the assumed behaviour of firms and displays properties consistent with the data?

On a conceptual level we might consider two broad approaches to modelling how firms set prices in an inflationary environment. The standard approach is to identify the optimum price for the firm at each point in time and then assume that the optimum price acts as an 'attractor' for the actual price set by firms. To model, and thereby, describe the evolution of the optimum price in a world where firms know and set the optimum price is equivalent to describing how prices actually evolve. In this world the converse is equally true. To describe how actual prices evolve with a price rule is equivalent to describing how the optimum price evolves.

The second approach is the one followed here. Consider the firm does not know the optimum price at each point in time and so the optimum price cannot act as an 'attractor' for the actual price that the firm sets. Now the actual price may evolve in a dissimilar fashion to the optimum price for extended periods of time. Consequently, if we describe how the actual price evolves with a price rule we may predict relationships in the data that might not be described, or even possible, using the standard approach. It follows that when the optimum price is not known by firms, how the actual price evolves in the data may be a poor representation of how the optimum price evolves. Furthermore, it may be easier to identify and estimate the rule by which actual prices evolve than to identify how the optimum price evolves.

An important property of the data that models of price behaviour should conform with and explain is the negative relationship between inflation and the markup. Richards and Stevens (1987), Bénabou (1992), Franz and Gordon (1993), Cockerell and Russell (1995), de Brouwer and Ericsson (1999), Simon (1999) and Batini, Jackson and Nickell (2000) have empirically identified a short-run negative relationship between inflation and the markup.[1] Furthermore, Banerjee, Cockerell and Russell (2001) and Banerjee and Russell (2000, 2001a, 2001b), Banerjee, Mizen and Russell (2002) argue the relationship is of a long-run nature in the Engle and Granger (1987) sense. To be consistent with the data, therefore, models of pricing behaviour should predict a negative relationship between inflation and the markup and that the relationship should display considerable persistence.

Explanations of these empirical findings can be separated into three broad groups in the literature. The first group builds on the well established arguments of Mankiw (1985) and Parkin (1986) that model the price setting behaviour of firms in the presence of 'menu' costs and includes papers by Rotemberg (1983), Kuran (1986), Naish (1986), Danziger (1988), Konieczny (1990) and Bénabou and Konieczny (1994). These papers argue that inflation has real economic effects and that inflation and the average markup may be related (usually in a negative fashion). The second group are the general equilibrium papers by Bénabou (1988, 1992), and Diamond (1993) who argue that the cost and/or demand functions are, in part, dependent on inflation and therefore inflation interacts directly with the profit maximising markup rather than on the average markup. The final group comprise the 'behavioural optimising' models of Russell, Evans and Preston (2002) and Chen and Russell (2002).

The first two groups of explanations do not explicitly consider whether inflation and the markup are related in the steady state?[2] Implicitly, these papers argue that the relationship is only of a short-run nature due to the wider macroeconomic models in which they are imbedded where real variables (such as the markup) are independent of inflation in the steady state.[3] In contrast, the behavioural optimising papers argue explicitly that inflation and the markup are negatively related in the steady state and may provide a basis for the persistence in the negative long-run inflation-markup relationship.

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1 Cockerell and Russell (1995) differ from the other papers in this group in that they solve their short-run empirical model and demonstrate a negative relationship between the markup and steady state inflation.

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

3 Bénabou (1988, 1992), and Diamond (1993) may be thought to describe a steady state relationship if changes in inflation permanently alter the level of search undertaken by agents.

The modelling strategy in all these papers is to *increase* the knowledge and sophistication of the rational agents until firms have no choice but to choose a unique price path when in disequilibrium from the optimum price. This is in contrast with the modelling strategy adopted here where we assume *less* information and sophistication rather than more. Indeed, economic agents not only operate under uncertainty and with incomplete information but also without the skills to choose the optimum price and price path.[4] Hence, assuming less information and sophistication rather than more adds a measure of realism to the analysis. This strategy may also lead to results that are excluded by assumption in full information models, models that assume profit maximisation or models that tightly define the nature of the missing information.

We proceed in the next section by proposing a ‘price rule’ that non-colluding price-setting firms follow when routinely adjusting prices in an inflationary environment and there is missing information.[5] The firm’s objective with the price rule is to avoid the cost of price coordination failure due to non-synchronous price adjustment in an inflationary environment.[6] The price rule conforms with two assumptions concerning the pricing behaviour of firms for given trading conditions. The first is, the lower the markup the greater the increase in prices set by firms. The second is, firms do not instantly and fully adjust prices in response to an increase in unit costs. That is, an increase in unit costs leads initially to a fall in the markup. We show how this price rule leads firms in an inflationary environment to synchronise their price increases.

Having modelled the pricing behaviour of firms in the short run, Section 3 investigates the steady state properties of the price rule. The model suggests that higher inflation is

4 An important distinction can be made between uncertainty and risk. The former suggests that not enough is known so an opinion can be formed on the latter. For a survey of the importance of this distinction see Lawson (1985).

5 The rules are formal, or following Machlup (1946), the ‘feel’ of the businessman.

6 Not withstanding the many possible coordination failures that firms may experience, this paper only considers the non-synchronous change in prices in response to generalised cost and price inflation. A number of authors highlight the inability of firms to coordinate price changes. For example, see Ball and Romer (1991), Eckstein and Fromm (1968), Blinder (1990) and Chatterjee and Cooper (1989).

associated with a lower markup in the steady state. The relationship is non-linear. At zero steady state inflation, the markup is at a maximum and, as inflation increases, the markup declines and converges on some minimum value. The empirically identified negative long-run relationship may be interpreted as the steady state relationship in this model. The declining markup as inflation increases in the steady state is the cost to firms of overcoming the missing information when trying to coordinate changes in prices. While the cost of avoiding price coordination failure increases with inflation, it does so at a declining rate.

## 2. A MODEL OF PRICE ADJUSTMENT

The model describes the *routine* pricing behaviour of non-colluding price setting firms in an environment that is, in general, inflationary and where aggregate inflation is determined by the monetary authorities. Firms are not undertaking strategic policies other than the policy to coordinate price changes between firms in response to their trading conditions and industry wide changes in costs so as to maintain the relative price of the firm's output unchanged.

The price changes are 'routine' in the sense that firms are repeatedly responding to general cost and price inflation. At the same time as firms are routinely adjusting prices they are trying to coordinate their price changes with competitors so as to avoid the adverse effects of inadvertently changing the relative price of their output. That is, firms that are routinely adjusting the nominal price of their output are wanting to avoid accidentally making real decisions due to changes in the relative price of their output.

As firms making routine price adjustments intend no change in the relative price of their output there is no need to adjust real variables *ex ante*. Furthermore, adjustment costs due to hiring and firing outweigh any benefits of adjusting real variables in response to small *ex post* fluctuations in the markup as firms believe the fluctuations will be transitory.[7] Therefore, it follows that with no expected change in the relative price of the firm's output the firm's real decisions concerning employment, the level of output, investment and the capital stock are independent of the routine adjustment of prices. Similarly, the market

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7 For adjustment costs see Bertola (1990, 1992), Bentolila and Bertola (1990), Booth (1995), Emerson (1988) and Nickell (1978, 1986).

structure of the industry and technology are exogenous with no entry or exit by firms are also independent of the routine adjustment of prices.[8] It is assumed that firms are acting symmetrically in the sense that all firms are only concerned with coordinating price changes in an inflationary environment so as to avoid the consequences of changes in relative prices.

Firms set prices freely in response to trading conditions and changes in costs. Trading conditions include expectations, customer behaviour and the growth in industry sales. The cost of inputs, including labour, is affected by many variables, most of which the firm has little influence over. Therefore the model focuses on the price decision over which firms control, as they respond to the trading conditions and changing costs which firms do not control. By not explaining what causes changes in costs or trading conditions, a large part of the explanation of inflation is avoided. This model does not attempt to explain aggregate steady state inflation which is determined by the monetary authorities but the steady state implications of the short-run pricing behaviour of firms.

Firms are rational and desire to maximise profits. However, due to missing information and uncertainty, they are incapable of the marginal analysis necessary to maximise profits and instead do the best they can. In particular, knowledge of the firm's demand and cost functions, competitors' costs and technology, and of existing and future competitors is incomplete. Firms do, however, know their markup of price on unit costs, unit costs and revenues in the preceding period.[9] Adding to the firm's uncertainty, the products, competitors and customers are heterogeneous.

Due to the uncertainty of the economic environment, firms find it difficult to coordinate price changes in response to their trading conditions and costs. The uncertainty leads to the formation of a customer market in which firms believe that a small change in the relative

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8 This issue is considered further following the steady state analysis.

9 The use of the markup on unit costs is not critical to the analysis as identical results are obtained using the markup on marginal costs. However, while the concept of marginal cost is easily understood with continuously differentiable production functions, marginal costs are difficult for firms to measure in practice due to the existence of joint products. The problem of joint products are considered by Marshall (1920, 1927), Sraffa (1960), Baumol (1976, 1977), Panzar and Willig (1977) and Willig (1979).

price of their output is not economically meaningful in the sense of no need to adjust real variables.[10]

Finally, firms have an expectation of trading conditions and set prices in response to this expectation and changes in actual costs. Trading conditions are in part dependent on the general inflationary environment and partly dependent on the business cycle. Therefore, expected trading conditions of the firm are measured in aggregate by the actual growth in the industry's nominal sales.[11] It is assumed that past errors in the firm's expected trading conditions are small enough to be ignored in relation to the firm's price decision but are incorporated in the actual markup at the beginning of each period.

The extent and type of missing information faced by firms influences the nature of the price adjustment.[12] The missing information is irrelevant in understanding the steady state relationship between inflation and the markup if the steady state led inexorably to firms discovering the missing information. In this case the steady state simultaneously implies profit maximisation in this model as well as in most standard models. A more practical conceptualisation of the steady state is the one assumed in this paper where average inflation of all nominal variables is the same constant rate and that *the missing information is not of the type that can be discovered by firms* by simply knowing nominal demand and costs are growing at a constant steady rate. In this case, firms may systematically deviate from the full information profit maximising markup in the steady state simply because the information

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10 In particular see Okun (1981) for a description of customer markets. Alternatively, see McDonald and Spindler (1987), Rotemberg (1982a, 1982b).

11 The results are essentially the same if a real measure of trading conditions is used in this analysis. This issue is returned to in a later footnote. The use of a nominal measure of trading conditions is appealing in that nearly all firms produce multiple products and can easily measure nominal sales growth while measures of real sales require an index of prices and are considerably more complicated.

12 The assumption of symmetric behaviour of firms allows us to model the firm individually without reference to any strategic pricing behaviour. Avoiding the 'representative agent' assumption introduces the problem of how to aggregate the behaviour of the individual firms. However, we will see that in the steady state the firm's output price inflation is the same as aggregate inflation which is determined by the monetary authorities.

concerning how to coordinate moving to the full information profit maximising markup continues to remain 'missing'.

## 2.1 The Firm's Price Decision

The firm's decision to adjust prices in response to changes in unit costs and expected trading conditions conform to the following behavioural hypotheses:

The Cost Hypothesis: *'All else equal, firms do not fully adjust prices in response to an increase in costs'*

And:

The Demand Hypothesis: *'All else equal, the lower the firm's markup the higher the price response for given trading conditions'*

The cost hypothesis follows if firms believe they face an asymmetric loss function associated with a change in relative prices. In particular, the firm may believe that an increase in the relative price of their product due to non-synchronous price adjustment may cost the firm more than a decrease in the relative price. The asymmetry may exist due to the customer market where a change in price encourages search by some existing customers and the relative price determines whether the searching customer chooses another supplier. Having chosen a new supplier the customer is lost to the firm until encouraged to search by the new supplier. Therefore, the loss of customers due to the non-synchronous change in prices and the increase in the relative price may be long-term and unable to be reversed by simply correcting the relative price in the next period. Alternatively, the effects of a non-synchronous decrease in the relative price can be reversed in the next period.[13]

The economic intuition of the demand hypothesis is more complicated. The lower the markup the greater the cost of disequilibrium in terms of lost profits. By increasing the price

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13 Further explanations include increasing returns to scale or a 'kinked' demand curve. Both suggest that a high price and a low level of output have a greater impact on profits than a low price and high level of output.

of its output the firm can reduce the lost profits in disequilibrium but the larger the increase in prices the greater the threat and expected cost of price coordination failure. The firm faces a trade-off between a reduction in lost profits and an increase in the expected cost of price coordination failure. It follows, therefore, that all else equal, the lower the markup (and greater the lost profits in disequilibrium relative to the expected cost of coordination failure) the larger the price increase that firms will choose.

The cost and demand hypotheses subject the markup to two 'forces' in an inflationary environment. The first is the effect of rising costs that serve to reduce the markup via the cost hypothesis. The second is due to the demand hypothesis where firms desire to increase the markup to reduce the cost of disequilibrium subject to the fear of price coordination failure. Therefore, we can imagine an 'equilibrium' where these two forces are in balance and where the markup may be less than that desired by firms if there were full information and no threat of coordination failure. In this 'equilibrium' firms desire a higher markup but believe that if they adjust directly to the desired higher markup the cost of price coordination failure outweighs the advantages of a higher markup.

The decision to change prices is analysed here as two separate decisions; the response to costs and to trading conditions. However, the firm's actual price decision considers these issues simultaneously. In isolation the cost hypothesis may appear to represent 'irrational' behaviour as the firm accepts a continuously falling markup (and real profits) in an inflationary environment. However, taken together with the demand hypothesis the markup may rise, fall, or remain unchanged in response to higher costs.

The behavioural hypotheses can be stated more formally as a price rule. Consider a firm facing given trading condition, $\Delta ns_t$, and an increase in the unit costs, $\Delta uc_i$, of inputs $i_1, \ldots i_n$ (i.e. $i_1$ is labour, $i_2$ is energy etc). Consistent with the hypotheses above, the firm adjusts prices such that:

The Price Rule
$$p_t = p_{t-1} + \alpha_t \Delta ns_t + \sum_{i=1}^{n} \beta_i \Delta uc_{i,t} \qquad (1)$$

*The Cost Hypothesis* $$\sum_{i=1}^{n} \beta_i < 1 \qquad (2)$$

*The Demand Hypothesis* $$\alpha_t = \alpha_0 - \alpha_1 \Pi_{t-1} \qquad \text{for } \Delta ns > 0 \qquad (3)$$

where $p$, $ns$ and $uc$ are the price, nominal sales and unit costs respectively and lower case variables are in logs.[14] The markup $\Pi$ is defined as the markup of price on total unit costs and so $\Pi = P \Big/ \sum_{i}^{n} UC_i$ is the ratio of two levels.[15]

Three aspects of the price rule need to be addressed before we look more closely at the cost hypotheses. First, why is the price in each period related to the previous period's price? Tversky and Kahneman (1974) outline three heuristics in relation to judgement under uncertainty. The third heuristic, anchoring and adjustment, suggests people in an uncertain environment follow a decision process by choosing a relevant value, or anchor, and then adjusting from that anchor. If the adjustment was sufficient, the starting point would be immaterial. Most importantly however, the adjustment is usually insufficient. The existing price is the likely anchor as it is known; has been revealed as the preferred price in the previous period; provides the most recent price / output split of the firms nominal sales; and deviations from the existing price are relevant for dislodging customers in a customer market.

The second aspect is why the relevant variables are in change form and not in levels. Support for the use of changes rather than levels of variables comes from a number of sources.[16]

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14 While the model is developed assuming the economy is in general inflating, nominal demand in any particular period may fall. Using arguments similar to those outlined in this paper, it may be expected that $\partial\alpha_t / \partial\Pi_t > 0$ when $\Delta ns_t < 0$. That is, for a given fall in nominal sales firms will lower prices by more the higher is the markup.

15 A more general price rule would include an 'adjustment', $\gamma$, to the trading conditions term, such that $\alpha_t \Delta(\gamma + ns_t)$. The coefficient $\gamma$ represents the response of individual firms to industry-wide trading conditions. We assume that $\gamma = 0$ in the steady state otherwise the firm's expectations of trading conditions will persistently be either more or less optimistic than aggregate trading conditions.

However, the most compelling reason is the use of changes reduces the cost of information associated with deciding on a price by avoiding the collection of identical information in successive periods. Only ‘new’ information is necessary and this is captured by changes in the variables as ‘old’ information is already incorporated in the existing price.

Finally, why are prices adjusted for changes in actual and not expected costs? For price setting firms that can adjust prices at any time this is not unreasonable. Expected costs are more important when prices are externally fixed for a stipulated period. The actual cost assumption is, therefore, more relevant the larger the proportion of firms that retain the option to adjust prices. Casual observation would suggest this to be the large majority of price setting firms.

## 2.2 The Cost Hypothesis

Assuming firms do not *routinely* reduce their price nor increase their markup in response to repeated increases in unit costs then $0 \leq \sum \beta_i \leq 1$. However, we can argue that the cost coefficient lies strictly within these boundaries and that $0 < \sum \beta_i < 1$. First consider the upper boundary when $\sum \beta_i = 1$.[17] If the firm is uncertain of their competitors cost coefficients and they believe they face an asymmetric loss function as outlined above then it is optimal for a risk neutral firm to choose $\sum \beta_i < 1$. Firms therefore will not fully pass higher unit costs into higher prices and the markup falls following a cost increase. Given that all firms are acting symmetrically then $\sum \beta_i < 1$ for all firms. Hence the ‘gradual’ price adjustment strategy in response to an increase in costs.

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16 Machlup (1946) argues that economic theory is a theory of adjustment to change (albeit by marginal analysis). Kahneman and Tversky (1979) in their analysis of departures from expected utility theory state that changes rather than final states are important psychologically. Nelson and Winter (1982) model a world where the economy and the rules respond to changing conditions and the response depends, in part, on the initial conditions.

17 With $\sum \beta_i = 1$ prices are fully adjusted in response to the increase in unit costs and the markup is unchanged.

'Gradual price' adjustment relies on the idea that non-colluding firms are not able to be certain that $\sum \beta_i = 1$ for their competitors when routinely adjusting prices. That is, the *threat* of a non-synchronous price adjustment remains unless firms somehow learn conclusively that $\sum \beta_i = 1$ for all their competitors.[18]

Second, consider the lower boundary where $\sum \beta_i = 0$.[19] If the customer market allows small changes in relative prices to be 'economically meaningless' then the firm benefits in terms of higher profits by choosing a small increase in prices and $\sum \beta_i > 0$ with no cost associated with the consequent price coordination failure. Again, given that firms act symmetrically then all firms will choose $\sum \beta_i > 0$. The actual value of the cost coefficient, $\sum \beta_i$, will depend on the characteristics of the decision maker in response to the nature of the industry they operate in. The more risk averse the decision maker and the closer the substitutes (in both geographic terms of competing sellers and the characteristics of the product) the lower the value of $\sum \beta_i$.[20]

It may be argued that $\sum \beta_i = 1$ once lags in the pricing decision are considered. However, if the lag structure of a cost increase flowing into higher prices is not fixed and depends on trading conditions and the markup then one interpretation of the demand hypothesis is that it encapsulates a variable lag structure based on trading conditions and the markup. Alternatively if $\sum \beta_i = 1$ and the lag structure is fixed and *independent* of trading conditions and the level of the markup then the demand hypothesis is redundant. This alternative is a special case of the more general variable lag structure.

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18 In a sense this is a variation of Popper's (1983) falsification argument. No matter how often the firm observes that price changes are synchronised in the past a non-colluding firm cannot 'prove' that competitors will behave in the same way in the future.

19 If $\beta = 0$ the firm leaves prices unchanged following an increase in unit costs and the markup falls.

20 One particular value of the cost coefficient may be of interest. If $\sum \beta_i = 1/\Pi$ then nominal profits are unaffected by an increase in unit costs although the markup declines.

Finally the cost hypothesis is concerned with the firm's reaction to industry wide cost increases. It is likely that firms will pass on less of a firm specific cost increase than an industry wide one. The former is not a coordination problem of the sort considered here. However, part or all of firm specific increases will be passed into prices eventually via the demand mechanism as all firms face firm specific cost increases even though they differ in source, timing and size. If firm specific costs generally increase and were not eventually passed through into prices or offset by firm specific productivity increases then the markup would eventually fall to zero.[21]

## 2.3 Coordinating Price Changes and Convergence to the Steady State

Firms may choose different price changes in the short-run for three reasons. First, each firm's initial markup may differ. Second, their expectation of trading conditions may differ. Third, the behaviour of the decision makers and the information available to them may be different. That is, the coefficients of the demand and cost hypotheses may differ between firms. While firms may in the short-run choose different changes in price this is not sustainable in the steady state. The demand hypothesis eventually coordinates price changes by changing the relative markups of firms leading to output prices and costs growing at the same rate in the steady state.

The price coordination leading to convergence to the steady state can be explained in the following way. Begin by assuming that the monetary authorities 'target' a rate of aggregate inflation and that unit costs are growing in line with this 'target' rate of inflation. If the firm's output price inflation is less than the 'target' rate then the markup will fall and the firm's output price inflation will increase due to the demand hypothesis. The converse occurs if the output price inflation is greater than the 'target' rate of inflation. The process stops when the firm's prices are increasing in line with the 'target' rate of inflation and unit costs. The markups of each firm in the steady state are not necessarily the same and will reflect the heterogeneous nature of firms, decision-makers and the industry. However, *output*

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21 One implication of this distinction between firm specific and industry-wide cost increases is that if the unit cost variable contains both types of cost increases then empirical estimates of the cost coefficient will be biased downwards.

*price inflation* will be the same for all firms  in the steady state and equal to the ‘target’ rate of inflation and unit cost inflation.

This explanation appears to rely heavily on the assumption that unit costs are growing in line with the ‘target’ rate of inflation. However, this assumption only simplifies the argument and does not affect the conclusion. If unit costs are growing by less than the ‘target’ rate of inflation then the firm’s prices will also be growing by less than the ‘target’ rate. This cannot represent a steady state solution. Either unit cost inflation must increase or the monetary authorities must reduce the ‘target’ rate of inflation. If there is no change in the ‘target’ rate of inflation then, presumably, output is growing above its trend rate of growth leading to falling unemployment and higher unit cost inflation until they eventually match the ‘target’ rate of inflation. Alternatively, the monetary authorities may respond to the low rate of unit cost inflation and reduce the ‘target’ rate. Again unit costs grow in line with the ‘target’ rate of inflation and eventually the firm’s output price inflation, aggregate inflation and unit cost inflation are all in line with the ‘target’ rate of inflation.

## 3. THE AGGREGATE PRICE RULE AND THE STEADY STATE

In the previous section a short-run price rule was proposed. This section considers the steady state properties of the short-run price rule and finds that the rule is sustainable in the steady state for the environment in which the rule is proposed: namely an inflationary environment.

Assuming the only inputs in the aggregate economy are labour and capital we can write the aggregate price rule in log form as:

$$\Delta p_t = \alpha_t (\Delta p_t + \Delta y_t) + \beta(\Delta w_t - \Delta\Phi) \tag{4}$$

where $\Delta\Phi$ is exogenous growth in productivity, $w$ is the average wage rate and the growth in nominal sales is written $\Delta p + \Delta y$ where $y$ is real output. The markup identity is:

$$\Delta \pi_t \equiv \Delta p_t - \Delta w_t + \Delta\Phi \tag{5}$$

Assuming a constant labour force, output will grow with trend productivity in the steady state and $\overline{\Delta y} = \overline{\Delta\Phi}$.[22] If the monetary authorities 'target' a rate of inflation $\overline{\Delta p}$ then in the steady state $\overline{\Delta w} = \overline{\Delta p} + \overline{\Delta\Phi}$. From (3), (4) and (5), defining the steady state as $\Delta\Pi = 0$ and with $\overline{\Delta p}$, $\overline{\Delta y}$ and $\overline{\Delta w}$ at their steady state values then the steady state markup can be written:[23]

$$\overline{\Pi} = \frac{\alpha_0}{\alpha_1} - \frac{(1-\beta)}{\alpha_1}\left(\frac{\overline{\Delta p}}{\overline{\Delta p} + \overline{\Delta\Phi}}\right) \qquad \overline{\Delta p} + \overline{\Delta\Phi} \neq 0 \tag{6}$$

The solid line in Figure 1 shows the steady state combinations of the markup and inflation displayed in equation (6). We see that the steady state markup is at a maximum $\alpha_0/\alpha_1$ with zero steady state inflation. The firm has achieved its desired markup and, as there is no inflation, prices are not changing and there is no threat of price coordination failure. At the other extreme, the minimum steady state markup converges on $\frac{\alpha_0 - 1 + \beta}{\alpha_1} > 0$ as $\overline{\Delta p} \rightarrow \infty$ with $\alpha_0 > \alpha_1$.[24] Below this minimum level of the markup, the expected cost of coordination failure is so low relative to the lost profits in disequilibrium that firms raise prices and increase their markup.

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22 The bar over the variable indicates its steady state value.

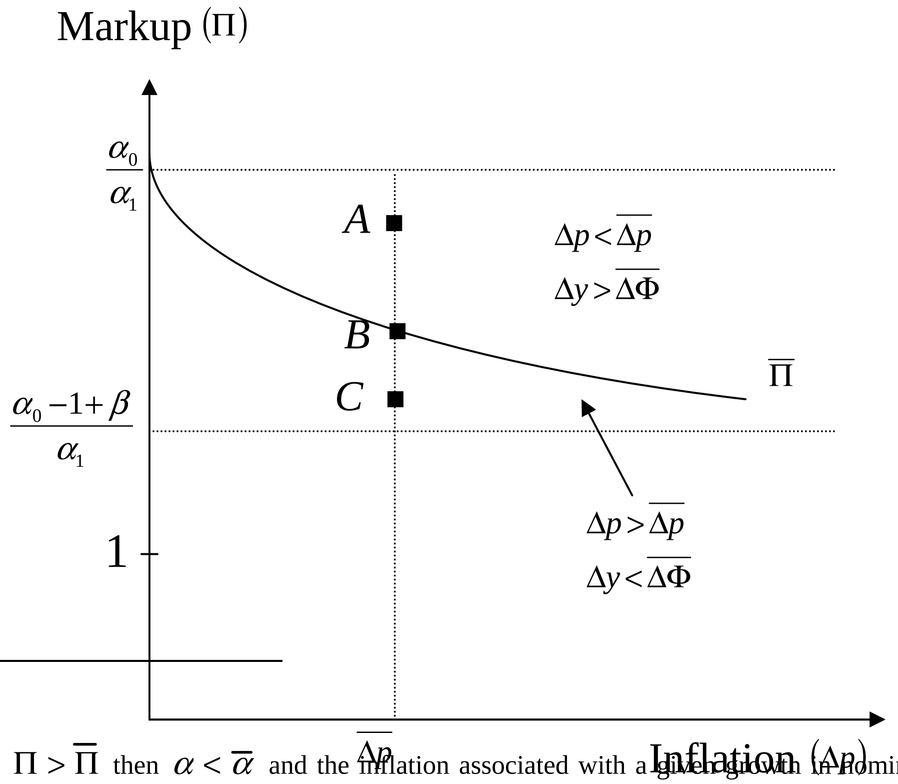
23 If a real measure of trading conditions, such as the output gap, is used rather than a nominal measure then (6) becomes $\overline{\Pi} = \frac{\alpha_0}{\alpha_1} - \frac{(1-\beta)\overline{\Delta p}}{\alpha_1}$. In this form the markup is linearly decreasing with inflation. This may be a good approximation over a narrow range of inflation but cannot in general be true. If the marginal cost markup is used instead of the unit cost markup then (6) is unaffected.

24 Price setting firms imply that $\alpha_0/\alpha_1 > 1$ at zero inflation and given $0 < \beta < 1$ then the minimum markup is greater than zero. If price-setting firms leave the industry when $\alpha_0/\alpha_1 < 1$ then $\alpha_0/\alpha_1$ will increase until $\alpha_0/\alpha_1 > 1$.

For non-negative rates of inflation the steady state curve in Figure 1 separates the area $\frac{\alpha_0 - 1 + \beta}{\alpha_1} < \overline{\Pi} \leq \frac{\alpha_0}{\alpha_1}$ into two regions. Above the steady state curve the markup is greater than its steady state value for a given setting of monetary policy. This implies the demand coefficient is less than its steady state value and, therefore, inflation is less than, and output growth greater than, their steady state values. Below the steady state curve the reverse holds with the demand coefficient and inflation both higher and output growth lower than their steady state values.

Starting at points above and below the steady state curve we can demonstrate convergence to the steady state value of the markup. Consider point 'A' in Figure 1 with the monetary authorities having set monetary policy, $\overline{\Delta p}$. As 'A' is above the steady state curve then $\Delta p < \overline{\Delta p}$ and $\Delta y > \overline{\Delta \Phi}$. Assuming that unit costs increase in line with aggregate inflation the 'pure mechanics' of convergence to the steady state is achieved as inflation is less than the growth in unit costs and the markup falls.[25]

**Figure 1: The Markup and Inflation in the Steady State**




25 As $\Pi > \overline{\Pi}$ then $\alpha < \overline{\alpha}$ and the inflation associated with a given growth in nominal demand is low relative to its steady state value and, therefore, also low relative to the steady state growth in wages.

As the real wage is the inverse of the markup this adjustment to the steady state must be consistent with behaviour in the labour market which is not modelled here. The firms behaviour of reducing the markup from ‘A’ to ‘B’ is consistent with behaviour in the labour market because at ‘A’ $\Delta y > \overline{\Delta\Phi}$ and, presumably, unemployment is falling. This leads to higher real wages and a lower markup with the process stopping at ‘B’. The converse would occur between ‘C’ and ‘B’.

The partial nature of this steady state analysis is obvious. To investigate the full macroeconomic implications, the roles of labour and the monetary authorities need to be incorporated. In the steady state the markup desired by firms for a given setting of monetary policy must correspond with the real wage desires of labour. If not, then the steady state will be unstable. However, we might expect that the pricing decisions of firms may dominate in the steady state because firms set prices *after* wages. Therefore, the steady state relationship between inflation and the markup will dominate and that to understand the steady state relationship (as distinct from the short-run relationship) between inflation and real wages, one needs only to consider the pricing behaviour of firms. Russell (1996) considers some of these issues further and extends the analysis to incorporate the behaviour of labour and the implication for monetary policy.

### 3.1 Entry, Exit and the Steady State Relationship

Relaxing the assumption of a fixed industry structure with no entry or exit of firms modifies, but does not overturn, the results of the analysis above. Consider the case where the monetary authorities tighten monetary policy and there is a reduction in the steady state rate of inflation. The subsequent increase in the markup may lead to the entry of new firms. If the new entrants compete away all the increase in the markup this would imply that industry structure and the markup are independent of each other as there are two industry structures in the steady state associated with only one markup. To avoid this result we can conclude that the new entrants compete away only a proportion of the increase in the markup and the negative relationship between the markup and inflation is reduced but remains in the steady state.

An alternative way of making this argument is that if new entrants compete away all the increase in the markup then there is no incentive for new firms to enter the market. For the markup to encourage entry then the markup must not return to the level prior to the tightening in monetary policy. Ergo, the negative relationship may be reduced but not removed by the entry of firms into the industry.

## 5. CONCLUSION

This paper began by suggesting that in an inflationary world where firms know the optimum (or profit maximising) price then modelling the firm's optimum price is equivalent to identifying a price rule that models how actual prices evolve. However, in a world with missing information and the optimum price is unknown the two approaches may provide dissimilar predictions for how prices evolve.

The rules based model elaborated above is based on three important assumptions. First, firms do not know the exact optimum price. Second, for given trading conditions, the increase in prices by a firm is greater the lower the profitability of firms as measured by the markup of price on unit costs. And third, in response to a general increase in unit costs, firms do not fully adjust prices so that the markup is unchanged.

Solving for the steady state, the rules based model provide predictions that are at odds with standard models. If the rules based model is consistent with actual firm behaviour then the markup should be negatively related with rates of steady state inflation. This is in contrast with the standard models where real variables, such as the markup, are independent of inflation in the steady state. The empirical identification of a negative long-run relationship between inflation and the markup appears to be consistent with the rules based model and not the standard models.

A further prediction is the relationship between the markup and steady state rates of inflation is non-linear. At zero steady state inflation the markup is at a maximum and as inflation increases the markup declines and converges on some minimum value.

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