A Theory of Price Rigidity When Quality is Unobservable

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A Theory of Price Rigidities When Quality is Unobservable

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A theory of price and quantity adjustments in response to stochastic changes in demand is developed for competitive markets. The level of demand is observable but product quality is not. It is shown that the higher the serial correlation of demand, the more rigid are prices and the greater the change in outputs. If the correlation is low, prices are less rigid than when quality is observable; if it is high, they can be more rigid. Even with downward sloping demand and upward sloping supply curves, prices can be completely rigid.

1. INTRODUCTION

Early studies of price flexibility found that the effect of changes in demand differed significantly across industries. For example, Table I shows the nominal price and production drops from 1929 to 1933 given by Means (1935, p. 8) for various industries in the U.S. It can be seen that the prices of complex manufactured products, such as motor vehicles, varied much less and the industry outputs much more than those for goods such as agricultural commodities (see also Mills (1927)). Subsequent studies have documented the inflexibility of industrial prices but have not compared this with the price flexibility in other sectors (Stigler and Kindahl (1970); Carlton (1986)).

<table>
<thead>
<tr>
<th>Industry</th>
<th>Per cent drop in nominal prices</th>
<th>Per cent drop in production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural implements</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>Motor vehicles</td>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>Textile products</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Petroleum</td>
<td>56</td>
<td>20</td>
</tr>
<tr>
<td>Agricultural products</td>
<td>63</td>
<td>6</td>
</tr>
</tbody>
</table>

A number of partial equilibrium theories, such as those based on adjustment costs (Barro (1972)), costly search (Alchian (1969); Okun (1975)) and inventories and unfilled orders as buffers (Carlton (1978, 1979, 1983); Blinder (1982)), have been put forward to explain why prices might be inflexible and provide a foundation for the crucial macroeconomic assumption of rigid prices (for a survey see, e.g. Gordon (1981)). These theories provide plausible explanations of many price rigidities. However, it can be argued they do not satisfactorily explain why these factors should be so important for,
say, the motor vehicle industry but not for textile products. In addition, they do not explain the inflexibility of prices when the change in demand is widely observed and persists for a long time, even though it is this type of rigidity which is required in many macroeconomic models.

The purpose of this paper is to provide a theory of price rigidities which is consistent with these differences across industries and which can explain why prices often do not adjust very much even when demand changes are persistent. It can be seen from Table I that one characteristic of the industries where prices are inflexible is that product quality cannot be easily observed, whereas in those industries where prices are flexible this is more straightforward. For example, observing the durability of agricultural machinery or automobiles is relatively difficult compared with observing the characteristics of petroleum or agricultural commodities. In the former type of market the reputation of the producer is much more important than in the latter. This suggests a theory of price adjustment where product quality is unobservable and reputation matters may be consistent with these observations. A model of this type is developed below. It is an extension of the one in Allen (1984).

In the standard theory of price adjustment, changes in price and output depend on the elasticities of demand and supply. With downward sloping demand and upward sloping supply curves, both the price and the quantity produced by each firm are higher in an industry boom than in a recession. In markets where quality is unobservable and reputation matters this is not necessarily so. The reason changes in demand can have different effects in this case is that prices must provide firms with the correct incentives to produce high rather than low quality. In particular, the expected future profits from maintaining a reputation for high quality must exceed the cost savings that would be obtained if low quality were produced this period. When this constraint binds there is a wide range of possibilities.

If demand is serially uncorrelated then expected future profits from high quality are independent of current demand. This means the potential cost savings if low quality were produced must also be independent of demand. These savings depend only on the quantity a firm produces. Outputs are therefore the same in every state of demand and all adjustment is through prices. If demand is positively serially correlated, a boom in the current period is likely to be followed by booms in subsequent periods. Usually this implies the expected future profits from maintaining a reputation for high quality are greater in booms than in recessions. Thus the potential cost savings if low quality were produced, must be larger when demand is high. Since the marginal cost of high quality is assumed to exceed that of low quality, this means firms' outputs in booms are higher than in recessions. The greater the serial correlation of demand, the larger this difference is. More adjustment is through quantity changes and less is through price changes. In contrast to the case where quality is observable, it is possible for prices to be rigid and all adjustments to be through changes in quantities.

The paper proceeds as follows. In Section 2 a simple partial equilibrium model with stochastic demand is outlined. Section 3 considers price and quantity adjustments when quality is observable. Section 4 then does the same when quality is unobservable. In Section 5 the two cases are compared. Finally, Section 6 contains concluding remarks.

2. THE MODEL

The model is a development of the one in Allen (1984), the main differences being that demand is stochastic rather than static and consumers are heterogeneous.
The product market considered is competitive: there is a continuum of identical firms. The integral sum of firms is \( n \). Time is divided into discrete periods: at the beginning of each, firms make their production decisions, then produce their output and finally attempt to sell it. For simplicity, it is assumed output cannot be stored. It is then optimal for the level of output to be equal to the level of sales and they are therefore not distinguished below. All costs and revenues are given in terms of end-of-period monetary units. Firms have an infinite horizon. To enter the industry, it is necessary to make an initial investment \( I > 0 \) which cannot be recovered. All firms are risk neutral. The rate of interest, which is constant through time, is \( r > 0 \).

If a firm produces no output it incurs no costs. If a firm produces a positive level of output, it incurs a cost of \( f_H(x) \) and \( f_L(x) \) for \( x \) high and low quality units of the product, respectively. To allow for such things as managerial overheads, recoverable investment costs and so on, there may be fixed costs which are only incurred at positive levels of output. These are larger for high quality:

\[
f_H(0) > f_L(0) \geq 0.
\]  

(1)

The marginal cost of a high-quality product is always greater than that of a low-quality product and cost functions are increasing and convex:

\[
f'_H(x) > f'_L(x)
\]

(2)

\[
f''_H(x) > 0; \quad f''_L(x) > 0
\]

(3)

Except where otherwise stated each firm's output \( x \) is observable.

There is a continuum of heterogeneous consumers. Everybody's utility is a decreasing function of price. They are each prepared to purchase one unit of the high-quality product every period, provided the price is sufficiently low. There are two levels of demand which could, for example, correspond to different levels of consumer incomes. In industry booms (state \( B \)) demand is high, and in recessions (state \( R \)) it is low. In state \( j (j = B, R) \) the integral sum of demands is \( X_{Dj}(p) \). The inverses of \( X_{DB}(p) \) and \( X_{DR}(p) \) are

\[
p_B = p_D(X_B) + \omega
\]

(4)

\[
p_R = p_D(X_R)
\]

(5)

where

\[
\omega \geq 0.
\]

(6)

The demand curves in both states are downward sloping:

\[
p'_D(X) < 0.
\]

(7)

It is public knowledge what the state of demand is for the current period when production and purchase decisions are made (i.e. \( \omega \) is observable).

If demand is in state \( j \) now, the probabilities it will be in state \( B \) and state \( R \) next period are \( \pi_j \) and \( (1 - \pi_j) \) respectively. The level of demand is either uncorrelated over time or positively serially correlated:

\[
\rho = \pi_B - \pi_R \geq 0
\]

(8)

where \( \rho \) is the serial correlation of demand (i.e. \( \text{cov}(X'_{Dj}, X'_{Dj+1})/(\text{var} X'_{Dj} \text{var} X'_{Dj+1})^{1/2} \)). The case where demand is negatively serially correlated can be similarly analysed.
The low quality product is so bad consumers are never prepared to pay anything for it:

$$X''_D(p) = 0.$$  \hfill (9)

Rational expectations are assumed: consumers and firms know the structure of the model.

3. PRICE AND QUANTITY
ADJUSTMENTS WHEN QUALITY IS OBSERVABLE

For the purpose of comparison, the case where quality is observable is briefly considered in this section. (A full derivation of the results is contained in Allen (1985).) A Nash-Bertrand equilibrium concept is used so that firms set prices taking all other prices as given. In equilibrium each firm sets price equal to marginal cost in both states in the usual way:

$$p_j = f'_H(x_j).$$ \hfill (10)

In the high profit state, firms enter until the expected discounted profits are equal to the sunk entry cost. In the low profit state, expected discounted profits are less than the sunk entry cost. Firms do not leave the industry though, since from (3) and (10) price exceeds average variable cost and discounted profits are still strictly positive. Thus the number of firms is the same in both states:

$$X_j = nx_j.$$ \hfill (11)

Given this, it can be shown that profits are higher in booms than recessions so that in equilibrium

$$V_B = I > V_R > 0$$ \hfill (12)

where $V_j$ is the expected discounted stream of profits in state $j$. For sufficiently large shifts in demand, price will not exceed average variable cost in recessions and firms will leave the industry until $V_R = 0$ for those remaining. This case is discussed in Section 6.

One possible measure of price rigidity is

$$\Delta p = p_B - p_R.$$ \hfill (13)

However, if the change in demand is large then $\Delta p$ could also be large even if prices are fairly inelastic. A better measure is $\Delta p / \omega$. For small $\omega$ this is equal to $d \Delta p / d \omega$ which is used below. Similarly, the measure of output rigidity used is $(p/x)(d x/d \omega)$ where

$$\Delta x = x_B - x_R.$$ \hfill (14)

These are found in the following way. Starting at $\omega = 0$, so that the equilibrium is at the intersection of the marginal and average cost curves $(p_1, x_1)$, the effect of increasing $\omega$ on $\Delta p$ and $\Delta x$ is considered. Differentiating (4), (5), (10) and (12) with respect to $\omega$, evaluating at $\omega = 0$ and solving simultaneously allows $dp_1/d \omega$, $dx_1/d \omega$ and $dn/d \omega$ to be found in terms of the short-run industry elasticities of demand and supply, $\varepsilon_D$ and $\varepsilon_S$ evaluated at $(p_1, x_1)$ where:

$$\varepsilon_D^{-1} = -\frac{X}{p} p''_D(X) > 0$$ \hfill (15)

$$\varepsilon_S^{-1} = -\frac{X}{p} f''_H(x) > 0.$$ \hfill (16)
These together with (13) and (14) give:

**Proposition 1.** When quality is observable, the changes in price and quantity resulting from a small stochastic shift in demand are:

\[
\frac{d\Delta p}{do} = 1 - Z_S
\]

(17)

\[
P \frac{d\Delta x}{x \, do} = \varepsilon_D Z_S
\]

(18)

\[
0 \leq Z_S \leq 1
\]

(19)

where

\[
Z_S = \frac{\varepsilon_D^{-1}}{\varepsilon_D^{-1} + \varepsilon_S^{-1}}.
\]

(20)

The shift in demand from state R to state B causes increases in price and the quantity produced by each firm. The degree of price rigidity depends on Z_S. The greater this is, the less the adjustment is through prices and the more it is through quantities. These adjustments depend only on \(\varepsilon_D\) and \(\varepsilon_S\) and are independent of \(\rho\). It will be seen in the next section that when quality is unobservable this is no longer true.

Two examples which are useful for comparison with the case where quality is unobservable are the following.

Example (i): \(f_H(x) = 2x^2 + 2x + 6; f_L(x) = x^2 + x + 1; p_D(X) = X^{-1}; r = 0.1; \)
\(I = 10; (p_1, x_1) = (9.48, 1.87); \varepsilon_D = 1; \varepsilon_S = 1.27; Z_S = 0.56.\)

Example (ii): \(f_H(x) = 10x^2 + 2x + 100; f_L(x) = x^2 + x; p_D(X) = X^{-0.5}; r = 1; \)
\(I = 110; (p_1, x_1) = (93.65, 4.58); \varepsilon_D = 2; \varepsilon_S = 1.02; Z_S = 0.34.\)

In the first example, adjustment to small stochastic shifts in demand is spread roughly evenly between price and quantity changes. In the second, adjustment is more through prices than quantities.

4. **Price and Quantity Adjustments When Quality is Unobservable**

(a) **Firms' outputs observable**

In this section quality is unobservable and there is no scope for warranties or any other means of directly certifying quality. Initially, each firm's level of output is assumed to be observable. It is simplest to start by considering the stationary Nash equilibrium when demand is static so \(X_{DB}(p) = X_{DB}(p) = X_D(p)\). Since a full analysis of this is given in Allen (1984) only a brief discussion is included here.

If a firm sells low quality products at high quality prices, buyers discover this only after they have purchased the product. Their evaluation then becomes known to other consumers through market surveys and so on, and the firm acquires a bad reputation. Consumers have expectations that once a firm has acquired a bad reputation, it will only ever produce bad quality in the future. Given these expectations, it is not worthwhile for firms with bad reputations to produce good quality and hence the consumers' expectations are self-fulfilling. Many such equilibria exist but this one Pareto-dominates the other possibilities.
Although consumers cannot directly observe quality before purchase, they can each use the price charged and the quality produced by a firm to check that the high quality claimed is in fact the most profitable quality. If a firm produces low quality, then it loses its reputation and cannot make any sales subsequently. Since all cash flows are in end-of-period monetary units, the present value of producing low quality evaluated at the beginning of each period, when the firm makes its production decision, is therefore \([px - f_L(x)]/(1 + r)\). If a firm chooses to produce high quality, it maintains its reputation and receives a steady stream of profits with present value \([px - f_H(x)]/r\). High quality will be more profitable if and only if:

\[
V = \frac{px - f_H(x)}{r} \leq \frac{px - f_L(x)}{1 + r}.
\] (21)

The boundary values of \(p\) and \(x\) such that (21) is satisfied are referred to as the moral hazard curve and denoted \(p_{MH}(x)\). Rearranging (21) gives

\[
p_{MH}(x) = \frac{f_H(x) + r[f_H(x) - f_L(x)]}{x}.
\] (22)

If \(p < p_{MH}(x)\) consumers infer low quality and are unwilling to purchase the firm’s output (from (9)). If \(p\) and \(x\) are such that \(p \geq p_{MH}(x)\) then (21) is satisfied. Consumers expect high quality since this is the profit maximizing choice and are prepared to buy from the firm. Thus if the intersection of the average and marginal cost curves \((p_1, x_1)\) lies above the moral hazard curve, the equilibrium is the same as if quality is observable and the analysis of the previous section holds. However, if the average and marginal cost curves intersect below the moral hazard curve then, if it exists, equilibrium occurs at the intersection of the moral hazard and average cost curves. This is the case considered below. A typical example \((p_2, x_2)\) is illustrated in Figure 1, which corresponds to Example (i). The number of firms is such that \(p_n(x)\) (where \(p_n^{-1}(x) = X_d(p)/n\)) passes through \((p_2, x_2)\) and \(V = I\).

\[\text{Figure 1}\]
\[\text{Equilibrium with static demand when quality is unobservable}\]
In Figure 1 an equilibrium exists because the moral hazard curve is upward sloping at \((p_2, x_2)\), and there are no points on it with positive profits and a lower price. Any firm attempting to increase its profits by cutting price and raising output has an incentive to produce low quality so consumers will not be prepared to purchase its products. This argument does not always hold. Differentiating (22) gives

\[
\varepsilon_{MH}^{1} \frac{xp'_{MH}(x)}{p} = \frac{r}{p}[f'_{H}(x) - f'_{L}(x)] + \frac{f'_{H}(x) - p_{MH}(x)}{p}
\]  

(23)

where \(\varepsilon_{MH}^{1}\) is the elasticity of the moral hazard curve. For \(p_{MH}(x) > f'_{H}(x)\) it is possible that \(\varepsilon_{MH}^{1} < 0\) as in Example (ii). When a firm’s output is observable an equilibrium does not exist in this case: a firm could always increase its profits and still have the right incentives for high quality if it cuts its price below \(p_2\) and increases its quantity slightly above \(x_2\). In order for equilibrium to exist it is necessary that

\[
\varepsilon_{MH}^{1} > 0.
\]  

(24)

Next consider what happens when demand is stochastic. Similarly to Section 3, suppose initially \(\omega = 0\) and the industry is in equilibrium at the intersection of the moral hazard and average cost curves \((p_2, x_2)\) with

\[
p_2 > f'_{H}(x_2).
\]  

(25)

Then consider the effect on \(\Delta p\) and \(\Delta x\) of increasing \(\omega\) a small amount. As in (21) it is necessary that

\[
V_j = \frac{1}{1+r}[C_j + \pi_j V_B + \pi_j V_R] \geq p_j x_j - f'_{L}(x_j),
\]  

(26)

where

\[
C_j = p_j x_j - f'_{H}(x_j),
\]  

(27)

in order for firms to have the correct incentives to produce high quality. For sufficiently small changes in \(\omega\), the equations (26) must be satisfied with equalities for an equilibrium to exist. To see this note that (26) is equivalent to

\[
\gamma_B C_B + (1 - \gamma_B) C_R \equiv r[f'_{H}(x_B) - f'_{L}(x_B)]
\]  

(28)

\[
\gamma_R C_B + (1 - \gamma_R) C_R \equiv r[f'_{H}(x_R) - f'_{L}(x_R)]
\]  

(29)

where

\[
\gamma_B = \frac{r \pi_B}{1 + r - \pi_B + \pi_R} \leq \gamma_R = \frac{1 + r \pi_R}{1 + r - \pi_B + \pi_R}.
\]  

(30)

Provided the change in \(\omega\) is small enough it follows

\[
p_j > f'_{H}(x_j).
\]  

(31)

Suppose (28) was satisfied with a strict inequality. This could not be an equilibrium because a firm could cut its price \(p_B\) and increase \(x_B\) so that (29) is still satisfied. Since \(p_B > f'_{H}(x_B)\), \(C_B\) and hence \(V_B\) are increased while (29) remains satisfied. Hence the original situation with a strict inequality is not an equilibrium. Similarly with (29) if it is satisfied with a strict inequality. Thus in equilibrium (28) and (29) must be equalities.

Using these together with (26) (with an equality) and (23), gives

\[
\frac{dV_B}{d\omega} - \frac{dV_R}{d\omega} = x[f'_{H}(x) - f'_{L}(x)]/p > 0.
\]  

(32)
The sign follows from (2), (24) and (25) which imply
\[ \rho \varepsilon_{D}^{-1} + \varepsilon_{MH}^{-1} + (1 - \rho)\left[1 - f_{L}^{e}(x)/p\right] > 0. \]  
(33)

Thus, expected profits are larger in booms when demand is high than in recessions. This implies the free-entry condition determining the number of firms in the industry is again (12). Also the discounted stream of profits when demand is low is strictly positive as in (12) so firms do not leave the industry and (11) is satisfied in booms and recessions. Since (26) always holds firms do not find it worthwhile to cash in their reputations at any stage. The case where shifts in demand are large enough to cause firms to leave the industry in recessions is discussed in Section 6.

Differentiating (4), (5), (12), (28) and (29) with respect to \( \omega \), evaluating at \( \omega = 0 \) and solving simultaneously it can be shown that

\[ \frac{dp_{B}}{d\omega} = 1 - \varepsilon_{D}^{-1} \left[ \frac{p}{x} \frac{dx_{B}}{d\omega} + \frac{p}{n} \frac{dn}{d\omega} \right] \]  
(34)

\[ \frac{dp_{R}}{d\omega} = -\varepsilon_{D}^{-1} \left[ \frac{p}{x} \frac{dx_{R}}{d\omega} + \frac{p}{n} \frac{dn}{d\omega} \right] \]  
(35)

\[ \frac{p}{x} \frac{dx_{B}}{d\omega} = \frac{-(1 - \pi_{B})}{\rho \varepsilon_{D}^{-1} + \varepsilon_{MH}^{-1} + (1 - \rho)\left[1 - f_{L}^{e}(x)/p\right]} < 0 \]  
(36)

\[ \frac{p}{x} \frac{dx_{R}}{d\omega} = \left(1 + \frac{p}{1 - \pi_{B}}\right) \frac{p}{x} \frac{dx_{B}}{d\omega} < 0 \]  
(37)

\[ \frac{p}{n} \frac{dn}{d\omega} = -\varepsilon_{D}^{-1} \left[ \varepsilon_{MH}^{-1} + (1 - \pi_{R})\varepsilon_{D}^{-1} + \pi_{R}\left[1 - f_{L}^{e}(x)/p\right]\right] \frac{p}{x} \frac{dx_{B}}{d\omega} > 0 \]  
(38)

where the signs follow from (24) and (33).

Proceeding as for Proposition 1 gives:

**Proposition 2.** When quality is unobservable, but firms’ levels of output are observable, the changes in price and quantity resulting from a small stochastic shift in demand are:

\[ \frac{d\Delta p}{d\omega} = 1 - Z_{MH} \]  
(39)

\[ \frac{p}{x} \frac{d\Delta x}{d\omega} = \varepsilon_{D} Z_{MH} \]  
(40)

\[ 0 \leq Z_{MH} \leq 1 \]  
(41)

where

\[ Z_{MH} = \frac{\rho \varepsilon_{D}^{-1}}{\rho \varepsilon_{D}^{-1} + \varepsilon_{MH}^{-1} + (1 - \rho)\left[1 - f_{L}^{e}(x)/p\right]} \]  
(42)

The degree of price rigidity is determined by \( Z_{MH} \) which in turn depends on \( \varepsilon_{MH} \), \( \varepsilon_{D} \), \( f_{L}^{e}(x)/p \) and \( \rho \). When \( \rho = 0 \), \( Z_{MH} = 0 \): all the adjustment is through price changes and none through quantity changes. To see why this is, consider (28). The left-hand side is the expected value of the future stream of profits starting at the end of next period given the current state of demand is \( B \). This represents the benefit from producing high quality. Since the revenue in the current period is independent of the quality produced,
the benefit from producing low quality is simply the difference in costs which is the right-hand side of (28). In order for firms to have an incentive to produce high quality, the left-hand side must be greater than or equal to the right-hand side. Similarly for (29). When \( \rho = 0 \), \( \gamma_B = \gamma_R \) and the future stream of profits is independent of the current state of demand. Hence the condition for high quality is the same in both states. Since the right-hand sides depend only on the quantity produced, it follows that \( x_B \) and \( x_R \) must be equal. Thus the entire adjustment to stochastic shifts in demand is through price changes. Clearly \( p_B > p_{MH}(x_B) \) and \( p_R < p_{MH}(x_R) \) and profits are greater if demand is high. This argument is independent of the specification of demand in (4). It depends only on the fact that when demand is uncorrelated the expected future stream of profits is the same in both states so the difference in costs and hence output must be the same in booms and recessions.

Differentiating (42) and using (23)

\[
\frac{\partial Z_{MH}}{\partial \rho} = \frac{\varepsilon_{D}^{-1}(1 + r)[f'_H(x) - f'_L(x)]/p}{\{p\varepsilon_{D}^{-1} + \varepsilon_{MH}^{-1} - (1 - \rho)[1 - f'_L(x)/p]\}^2} > 0
\]  (43)

with the sign following from (2). When the correlation coefficient increases more adjustment occurs through quantity changes and less through price changes. The reason is that the benefit from producing high quality, which is the expected discounted stream of future profits, is now higher in state \( B \) than in state \( R \). This is because it is more likely there will be booms subsequently. Hence the left-hand side of (28) is greater than the left-hand side of (29). The same must be true for the right-hand sides. Since \( f'_H(x) > f'_L(x) \) output must be greater in state \( B \) than state \( R \). This leads to more adjustment being through prices and less through quantities.

To see this diagramatically, first note that it follows from \( V_B > V_R \) that

\[ p_B > p_{MH}(x_B), \quad p_R < p_{MH}(x_R). \]  (44)

It can be seen from (38) that as \( \omega \) increases the number of firms in the industry also increases and \( p_{AB}(x) \) shifts downwards. Differentiating (4) with respect to \( \omega \), substituting from (38) and holding \( x \) constant

\[
\frac{dp_{nB}}{d\omega} = -[\varepsilon_{D}^{-1} - 1 + f'_L(x)/p] \frac{p}{n} \frac{dn}{d\omega}.
\]  (45)

If \( \varepsilon_D \) is large, \( [\varepsilon_{D}^{-1} - 1 + f'_L(x)] < 0 \) and using (38), \( p_{nB}(x) \) shifts upward. This case is illustrated in Figure 2. If \( \varepsilon_D \) is sufficiently small, then \( p_{nB} \) shifts downward. In both cases the greater is \( \rho \), the bigger the difference between \( x_B \) and \( x_R \) and the more the adjustments to shifts in demand are through quantities rather than prices.

Next consider Example (i) for various possible \( \rho \).

**Example (i):** \( (p_2, x_2) = (9.49, 1.79); \varepsilon_D = 1; \varepsilon_{MH} = 74; \rho = 0; Z_{MH} = 0; \)
\( \rho = 0.5; Z_{MH} = 0.65; \rho = 0.99; Z_{MH} = 0.98. \)

When demand is serially uncorrelated, all adjustment is through prices and none is through quantities. When serial demand is almost perfectly correlated nearly all adjustment is through quantities and none through prices. In contrast, in Section 3 where quality is observable, adjustments to shifts in demand are roughly evenly split between price and quantity changes, independent of the serial correlation of demand.
(b) Firms' outputs unobservable

So far it has been assumed firms' outputs are observable. In many applications this is an appropriate assumption, but in others it is not. As argued in Allen (1984) for the static case, even when outputs are unobservable, consumers still have enough information given prices to work out firms' outputs. However, when firms' outputs are unobservable (24) no longer holds and an equilibrium may exist with $\epsilon_{MH} < 0$. This case can be analysed similarly to Section 4(a). (The full details are again in Allen (1985).)

There are two main differences. If (33) is satisfied, it is possible to proceed as before in analysing the effect of small stochastic shifts in demand on prices and quantities. The first difference is that if $\rho$ is sufficiently high then $Z_{MH} < 1$: the change in prices has the opposite sign to the change in demand. A rise in demand leads to a fall in prices and vice versa. An example where this occurs is the following:

Example (ii): $\quad (p_2, x_2) = (222, 1); \quad \epsilon_D = 2; \quad \epsilon_{MH} = -1.23;\quad \pi_B = 0.3; \quad \pi_R = 0.1; \quad \rho = 0.2; \quad Z_{MH} = 1.36.$

The second difference is that unlike in Section 4(a), (33) is no longer always satisfied. In particular, it can be shown if $[\epsilon_D^2 - 1 + f'_L(x)/\rho] < 0$ and $\rho$ is sufficiently large, then it may not be. In such cases $dV_B/d\omega < dV_R/d\omega$ and expected profits are greater in recessions when demand is low than in booms when it is high. Instead of (12) the equilibrium condition becomes

$$V_R = I > V_B > 0.$$  \hspace{1cm} (46)

Proceeding as before it can be shown that $d\Delta p/d\omega$ and $(p/x)(d\Delta x/d\omega)$ are as in Proposition 2. Now however, $Z_{MH} < 0$ since (33) is not satisfied. This implies an increase in demand from state $R$ to state $B$ leads to a fall in quantities and a rise in price greater than the shift in the demand curve. It is an even more extreme example of price adjustment than when $\rho = 0$. An example of this is:

Example (ii): $\quad \rho = 0.5: \quad Z_{MH} = -3.46.$
The subsection is summarized by the following:

**Proposition 3.** When quality and firms' outputs are unobservable, price and quantity adjustments in response to small stochastic shifts in demand are the same as in Proposition 2. However, it is now possible that equilibria exist with $Z_{MH} > 1$ or $Z_{MH} < 0$.

5. COMPARISON

A comparison of Propositions 1 and 2 gives the situations where quality being unobservable leads to prices being more rigid than when it is observable. In Proposition 1 the degree of price rigidity depends on $Z_S$ where $\varepsilon_D^S$ and $\varepsilon_S^S$ are evaluated at the intersection of the marginal and average cost curves ($p_1, x_1$). In Proposition 2 the degree of price rigidity depends on $Z_{MH}$ where $\varepsilon_D^D$ and $\varepsilon_{MH}^D$ and $f'_l(x)/p$ are evaluated at ($p_2, x_2$). Any comparison depends on how $\varepsilon_D^D$ differs in the two situations. As a benchmark, it is convenient to consider the case where $\varepsilon_D^D$ is constant.

Given this, the question of when prices are more rigid depends critically on the serial correlation of demand $\rho$. Suppose $\varepsilon_{MH} > 0$, then $Z_{MH}$ is a continuous function of $\rho$ and from (42), $\partial Z_{MH}/\partial \rho > 0$. Since from (20) $\partial Z_S/\partial \rho = 0$, then if a value of $\rho$, denoted $\rho^*$, such that $Z_{MH} = Z_S$ exists it is unique. Using (20) and (42)

$$\rho^* = \frac{\varepsilon_{MH}^S + 1 - f'_l(x)/p}{\varepsilon_{MH}^S + 1 - f'_l(x)/p}$$

(47)

For $\rho$ above this value prices are more rigid when quality is unobservable, but for values below it they are less rigid. Note that in order for $\rho^*$ to lie in the feasible range between 0 and 1, it is necessary that $\varepsilon_{MH}^S < \varepsilon_{MH}^S$, given this, the larger $f'_l(x)/p$ the more likely are prices to have greater rigidity when quality is unobservable.

If $\varepsilon_{MH} < 0$ and $[\varepsilon_D^D + 1 - f'_l(x)/p] < 0$, then as discussed in Section 4(b), the denominator of $Z_{MH}$ may switch from being positive to negative. If this happens there is a discontinuity in $Z_{MH}(\rho)$. In this case, prices can be less rigid when quality is unobservable if $\rho$ is high.

All this is summarized by the following:

**Proposition 4.** If the elasticity of demand is constant, prices are more rigid with unobservable quality if $\rho > \rho^*$, except where profits are greater in the low state of demand. In that perverse case prices may be less rigid for some $\rho > \rho^*$.

6. CONCLUDING REMARKS

The theory above is developed for small shifts in demand since this allows price rigidities to be characterized in terms of simple elasticities. One implication of restricting attention to this case is that $V_B = I > V_R > 0$ (except in the perverse situation where profits are higher in recessions than booms in which case $V_B$ and $V_R$ are interchanged here and in what follows). As a result the number of firms in the industry is the same in both booms and recessions. This will not always be so. Clearly it is necessary in equilibrium that $V_R \geq 0$ since a firm can exit from the industry and obtain zero profits. For large enough shifts in demand this will be satisfied with an equality so that in recessions firms will leave until $V_R = 0$ for those remaining. One apparent possibility if a firm is to exit is that, since it loses its future stream of profits in any case, it might as well cheat and cash in on its reputation when the recession arrives. However, if $V_R = 0$ it follows from (26) that
\( p_B x_B - f_1(x_B) = 0 \) would be obtained from doing this. In other words it's not worthwhile for firms which are exiting to cheat since they do not gain anything from this. For those firms remaining, operating profits \( C_B \) are negative but these are balanced by the prospect of positive profits in the future when there is a boom. Thus the main difference when changes in demand are large is that the number of firms in booms and recessions can differ and there can be entry or exit whenever demand changes.

A number of the results are independent of the size of the change in demand. It follows from (28)--(30) that, whatever the magnitude of this, all adjustment is through price changes and none is through quantity changes when the serial correlation of demand is zero. As the latter increases more adjustment is again through changes in quantities. In general, it seems likely that other results will be similar when changes in demand are large. Of course, industry equilibrium depends on all the variables so that a change in any one of them will alter everything. However, ignoring these general equilibrium effects, the changes in prices and quantities when quality is observable should primarily be determined by the demand and supply curves, whereas when quality is unobservable they should mainly depend on the moral hazard curve and the serial correlation of demand. A full analysis of this case would require more specific assumptions about demand and cost functions.

The model assumes costs are constant. As with a number of other partial equilibrium analyses of price rigidities, such as those based on costly search and inventories and unfilled orders as buffers, it is therefore concerned with real rather than nominal price rigidities. This means that, by itself, the theory cannot form the foundation for an explanation of macroeconomic fluctuations. In order to do this, it would be necessary to have, in addition, a theory of wage and cost rigidities.

In recent years a number of other papers have also attempted to explain macroeconomic phenomena with unobservable quality of some sort (e.g. Shapiro and Stiglitz (1984)). Although these models differ significantly in their assumptions they share the feature that prices have two roles to play: they must allocate resources in the usual way and they must also provide incentives to agents to supply good quality. In many cases these roles conflict and as a result there is an inefficiency relative to the full information case.

In conclusion, when quality is observable the adjustment of prices and quantities in response to stochastic shifts in demand depends only on the elasticities of supply and demand. However, when quality is unobservable the degree of price rigidity depends crucially on the serial correlation of demand: the greater this is, the more rigid are prices (except possibly in the perverse case). The model is thus consistent with the observation that price flexibility in industries where the reputation of the producer matters is less than in industries where it does not. It also suggests that prices are likely to be more rigid the greater the likelihood a recession or boom will continue.

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