Reversing the Keynesian Asymmetry

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The assumption that nominal price adjustment is costly for firms (there are “menu costs”) has generated a stream of important theoretical papers over the last decade or so.[1] In so far as this literature generates asymmetric adjustments, it provides a theoretical underpinning for the (old) Keynesian assumption that nominal prices are more flexible upward than downward.[2] Yet, the empirical evidence, while confirming that asymmetries exist, does not indicate the dominance of any particular form of asymmetry (see Dennis W. Carlton, 1986; Alan S. Blinder, 1991). In this paper we argue that the gap between theory and practice may be the result of the focus of menu-cost models on specific forms of market structure. Existing menu-cost models are based on the assumption of relatively uncompetitive market structures – monopoly, oligopoly, or monopolistic competition with a fixed number of firms. We widen the scope of the analysis by examining what we call a quasi-competitive industry and demonstrate that it displays a pattern of adjustment quite different from that found in other models. The Keynesian asymmetry is reversed, with nominal price being more flexible downward than upward.[3] We suggest therefore that a relationship exists between market structure and the pattern of nominal price adjustment. Since there is presumably a variety of market structures, this may help explain the inconclusive empirical evidence.

We model the most competitive market configuration compatible with menu costs: Bertrand oligopoly in a dynamic setting with free entry. It is assumed that (a) an incumbent in one period can continue to sell at its existing nominal price in the next period without incurring any additional menu cost, whereas an entrant would have to incur a menu cost; and (b) among the firms willing to sell at the lowest price in any given period, one is chosen randomly to sell the product. These simplifications enable us to abstract from matters – such as determining the identity of active firms – extraneous to our main concern of establishing a clean connection between market structure and the pattern of price (in)flexibility. [4]

To set a benchmark and to obtain a simple solution by backward induction, we begin by assuming a two-period time-horizon. Then we extend the analysis to the case where the incumbent faces an ever-recurring threat of entry, that is, with an infinite horizon.[5] This is the scenario we call "quasi-competitive". Comparing these two extreme cases yields an intuitively appealing relationship between competitiveness and the pattern of nominal price adjustment. Whereas the two-period model produces some inflexibility in either direction, the increased competitiveness generated by the infinite horizon reverses the Keynesian asymmetry. Furthermore, the two-period case may be of independent interest, for it highlights a somewhat paradoxical result concerning the interpretation of price observations. We show that the observation of a small reduction in nominal price need not be taken as evidence that nominal price is flexible downward with respect to a reduction in a nominal scale variable.

Section I sets out the model, while Section II examines the solution. Section III places the model in the context of some related literature, and Section IV concludes. Proofs are relegated to the appendix.

I. The Model

Time is modeled in discrete periods, indexed by the subscript $t = 1, 2, ...$[6] Let N be a nominal variable (e.g., a cost-of-living index) subject to random shocks. Denote its realized value for period t by N_t, which is publicly observed at the start of the period. Realizations are independent draws from a probability distribution $y(N)$ defined over the compact support $[\underline{N},\overline{N}]$. We do not impose any restriction on $y(N)$ other than it being atomless. At the start of period 1 J riskneutral firms $(J \geq 2)$ become capable of supplying a new non-storable homogeneous good (or service).[7] In order to produce, any firm has to incur two types of cost: (a) a nominal menu cost mN_t (m in real terms); and (b) a constant marginal production cost N_t in nominal terms (unity in real terms).[8]

Upon observing N_t, each firm j ($j = 1,\dots, J$) simultaneously makes a bid to supply the product in period t. We denote firm j's nominal price bid by P_t^j, the corresponding real price being $p_t^j \equiv P_t^j / N_t$. Firms engage in Bertrand competition, but for any period t only *one* of the k $(1 \leq k \leq J)$ firms bidding the lowest price is chosen randomly to supply the good. This simplification may represent a situation where there exists some (small) exogenous asymmetry that allows a lowest-price firm to incur the menu cost before the others. Alternatively, the assumption fits the scenario of a central purchasing agency, where demand originates from decentralized units of a larger organisation, such as divisions of an M-form corporation or schools and hospitals operating under a local government agency. In these circumstances, it is common for the agency to select one supplier and let individual units order from the chosen firm according to their requirements (Peter J.H. Baily, 1987). Such contracts are generic, in that the chosen supplier provides the full menu only after agreeing terms with the agency.[9]

Throughout, we regard any firm that bids a new nominal price in period $t+1$ (different from the nominal price ruling at t) as a potential entrant in period $t+1$ – even if the firm concerned was the incumbent in period t. Also, if, for period $t+1$, the incumbent from period t offers to continue supplying at its period-t nominal price, we regard this as a bid like any other. Exit is assumed to be costless in the sense that if a firm becomes the incumbent (prints a new menu) in one period, it is under no obligation to supply the market in any subsequent period.[10] Let

$P_t \equiv \min_j \{ P_t^j \}$ be the lowest nominal price bid in period *t*, the corresponding real price being $p_t \equiv \min_j \{ p_t^j \}$. The time-invariant market demand for the product in period t is $D(p_t)$, where $dD(\cdot)/dp_t < 0$ and there exist values of p_t such that $D(p_t) > 0$.[11,12] The strong contestability flavor of our assumptions is summarized in

ASSUMPTION 1: *(i) if k $(1 \le k \le J)$ firms are willing to supply at the lowest nominal price P_t (p_t in real terms), then only one is selected (with prob. 1/k) to supply the entire demand $D(p_t)$; (ii) the menu cost is incurred only by the selected supplier (that is, after all price bids are revealed); (iii) at time t + 1, trade by the period-t incumbent is voluntary.*

Thus the demand function facing any firm j in period t is

$$(1) \qquad D^j(p_t^j, p_t^{-j}) = \begin{cases} \left.\begin{matrix} D(p_t) \text{ with prob. } 1/k \\ 0 \quad \text{with prob. } \dfrac{k-1}{k} \end{matrix}\right\} & \text{if } p_t^j = p_t \\ 0 & \text{if } p_t^j > p_t \end{cases}$$

where p_t^{-j} is the vector of price bids in real terms for period t by firms other than j, and k is the number of lowest-bid firms.[13]

We define $p(p_t)$ as the real gross profit (i.e., excluding any menu cost) earned by the sole supplier at time t :

$$(2) \qquad p(p_t) = D(p_t)[p_t - 1] \;.$$

Subtracting the real menu cost gives real net profit, $\eth(p_t) - m$. We define $\hat{p}_t$ by

$$(3) \qquad \eth(\hat{p}_t) - m \equiv 0 \,,$$

with $\hat{P}_t$ being the corresponding nominal price.

Let $p^{mon} \equiv argmax\ ð(p_t)$ denote the (unique) monopoly real price. Because of competitive bidding (see Assumption 1) no newly-set price can exceed p^{mon}. Therefore we restrict our analysis throughout to $p_t \in [0, p^{mon}]$ without loss of generality. We make the standard assumption

(4) $dð(p_t) / dp_t > 0$.

From (2)-(4) we obtain[14]

(5) $dð(p_t) / dN_t < 0$, $d\hat{P}_t / dN_t > 0$.

II. The solution

We now solve for the equilibrium nominal price vector, given that each firm's objective is to maximize the expected present value of its real net profit stream. Consider first a two-period world. For any pair of realized N, $\{ N_1, N_2 \}$, let $\{ P_1^*, P_2^* \}$ be the pair of equilibrium nominal prices, and $\{ p_1^*, p_2^* \}$ the corresponding pair of real prices.

PROPOSITION 1 (two-period case):

(i) $N_1 < P_1^* < \hat{P}_1$.

(ii) $$P_2^* = \begin{cases} \hat{P}_2 > P_1^* & if \quad N_2 \in (P_1^*, \overline{N}\ ] \\ P_1^* & if \quad N_2 \in [\hat{N}_2, P_1^*] \\ \hat{P}_2 < P_1^* & if \quad N_2 \in [\underline{N}, \hat{N}_2) \end{cases}$$

where $\hat{N}_2$ is defined by

(6) $$p (P_1^* / \hat{N}_2) = m .$$

Proof: see the appendix.

To see the intuition of this proposition, consider first period *2*. As exit is costless, there are only two potential equilibrium nominal prices for the one-shot Bertrand game played in this period: (a) a new menu is printed and a new nominal price charged which, because of the force of Bertrand competition, must be the break-even nominal price: $P_2^* = \hat{P}_2$; or (b) the incumbent can retain its period-*1* nominal price, $P_2^* = P_1^*$, without being undercut, thereby enjoying a positive real net profit.[15] Thus, in period *2* the incumbent either exits costlessly or makes a positive real net profit. Hence, as Bertrand competition requires the present value of the incumbent's expected real net profits over the two periods to be zero, the equilibrium nominal price in period *1* must yield a negative real net profit, that is, $P_1^* < \hat{P}_1$. In the appendix we show that the incumbent must make a positive real *gross* profit in period *1*, that is, $P_1^* > N_1$, otherwise the period-*1* loss could never be recouped in period *2*.

Figure 1 illustrates how the equilibrium nominal price in period *2*, P_2^*, adjusts to the period-*2* realizations of the nominal scale variable, N_2, for any arbitrary N_1, taking into account, as we have just indicated, that $N_1 < P_1^* < \hat{P}_1$.

Consider a realization $N_2 \in (P_1^*, \overline{N}]$. By retaining P_1^* the incumbent would earn a negative real net profit $D(P_1^* / N_2)(P_1^* - N_2)$, so it prefers to exit. The entrant's equilibrium nominal price P_2^* will allow it to break even: $P_2^* = \hat{P}_2 > \hat{P}_1 > P_1^*$, where the inequality follows from (5), given that $N_2 > N_1$. For N_2 ranging from P_1^* to $\overline{N}$, P_2^* lies on the **DE** segment in Figure 1.

Consider next a realization $N_2 \in [\hat{N}_2, P_1^*]$. At $N_2 = P_1^*$ the incumbent is indifferent between exiting and continuing to sell at P_1^*. Realizations of N_2 lower than P_1^* would earn positive real net profit from continued incumbency; but if N_2 is sufficiently small, an entrant can *both* match P_1^* *and* cover its menu cost. This happens at $N_2 = \hat{N}_2$, where $D(P_1^* / \hat{N}_2)(P_1^* - \hat{N}_2) = m\hat{N}_2$.[16] Therefore for $N_2 \in [\hat{N}_2, P_1^*]$, the equilibrium nominal price in period *2* lies on **BC** in Figure 1.

Finally, for realizations $N_2 \in [\underline{N}, \hat{N}_2)$, the incumbent is undercut by a breaking-even entrant setting $P_2^* = \hat{P}_2 < P_1^*$ (segment **AB** applies).

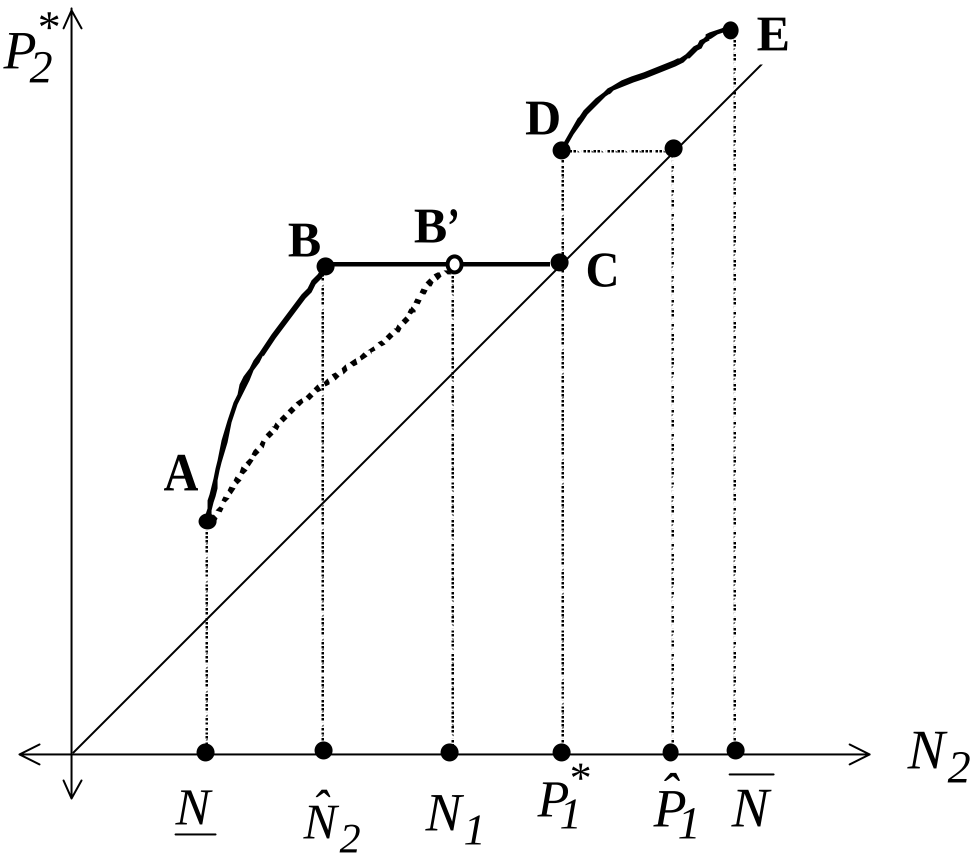

Figure 1

Thus, in the two-period case, Bertrand competition yields a two-sided *(s, S)* optimal nominal price adjustment rule. Note, however, a distinctive feature of adjustment in this case. Even though, as indicated by the segment **BB'**, there is downward inflexibility of nominal price with respect to N for all realizations $N_2 \in [\hat{N}_2, N_1)$, it can be seen from Figure 1 that P_2^* may fall below P_1^* by an arbitrarily small amount. This suggests that the magnitude of nominal price reductions observed in practice may be a misleading indicator of nominal price (in)flexibility with respect to the nominal scale variable.

When we extend the analysis to a quasi-competitive industry with nominal prices set under an infinite horizon, we find that nominal prices are perfectly flexible *downward*. This result is formalised in the following proposition, where, for simplicity, we focus on the adjustment (if any) of nominal price in period *2*:

PROPOSITION 2 (reversal of the Keynesian asymmetry under an infinite horizon):

(i) $N_1 < P_1^* < \hat{P}_1$;

(ii) $$P_2^* \begin{cases} > P_1^* & \text{if} \quad N_2 \in (P_1^*, \overline{N}] \\ = P_1^* & \text{if} \quad N_2 \in [N_1, P_1^*] \\ < P_1^* & \text{if} \quad N_2 \in [\underline{N}, N_1) \end{cases}$$

Proof: See the appendix.

The intuition behind Proposition 2 is similar to that for Proposition 1, with two major differences. First, an entrant in period 2 is no longer required to set a nominal price that yields zero real net profit in that period. Indeed, the equilibrium nominal price for an entrant will have to be such that it yields a zero expected value of the stream of real net profits over the infinite horizon, irrespective of the period of entry.[17] Second, because of the infinite horizon, in the event of N_2 falling short of N_1 by however small an amount, the incumbent can no longer retain the nominal price from the previous period without being undercut. In fact, an entrant in period *2* would face exactly the same prospects the incumbent had faced in period *1*, except that now the entrant enjoys a lower realization of N, and therefore can achieve a zero present value of the stream of real net profits by setting a nominal price lower than P_1^*. This is the source of the downward nominal price flexibility. In the event of a realization N_2 above N_1, similar logic yields the conclusion that, because of the higher nominal menu cost, P_1^* cannot be undercut. However, if $N_2 > P_2^*$ the incumbent's real net profit $D(P_1^* / N_2)(P_1^* - N_2)$ from continuing to sell at P_1^* would become negative.

The pattern of (nominal) price (in)flexibility that we have established for the first two realizations of N in the infinite-horizon case applies generally: P_t^* will be supplanted at the first realization of N falling outside $[N_t, P_t^*]$. Immediately following the period when a new nominal price is set, there is full downward flexibility, but partial upward flexibility. However, if N takes a value in the interior of $[N_t, P_t^*]$, a further marginal change in either direction has no effect on nominal price, while if the value of N reaches the upper bound P_t^*, a further small rise in N will be accompanied by a nominal price rise. Hence, the model is consistent with a variety of observations of nominal price adjustment and inflexibility. The critical difference between the two-period and the infinite-horizon cases is that in the latter the lower bound of the range of realizations of N_2 for which nominal price is unchanged turns out to be N_1 (as opposed to $\hat{N}_2 < N_1$ in the two-period case), so that any negative shock immediately following an adjustment in nominal price will always result in a lower nominal price. Therefore, under an infinite horizon, we obtain the reverse of the Keynesian asymmetry. In terms of Figure 1, the general shape of the adjustment curve survives, except that now it slopes downward not to the left of point **B**, but to the left of point **B'**, as shown by the broken curve **AB'**.

III. Some related literature

The model can be linked to several strands of the literature on nominal price adjustment. The contribution most closely related to ours is that by Julio Rotemberg and Garth Saloner (1987), who compare the nominal price adjustment, in the presence of menu costs, of a monopolist with that of duopolists. When a nominal scale variable is perturbed, they find some inflexibility, both upward and downward, in each market structure, but with greater inflexibility for the monopolist. Thus, they relate the *extent* of nominal price adjustment to market structure. Our contribution extends their logic, by showing that not only the extent, but also the *form,* of adjustment may change with market structure.

Secondly, there is a literature focusing on the labor market that argues that workers resist nominal wage cuts and so, if mark-ups are not too countercyclical, nominal prices tend to be inflexible downward. The contribution by Christopher Hanes (1993) is particularly pertinent here. In his analysis firms recognize that a nominal wage cut may result in a costly strike. In the case of an imperfectly competitive industry, the cost associated with the latter may offset the benefits of setting a lower nominal wage. In contrast, a competitive industry cannot sustain nominal wage (and price) rigidity as a Nash equilibrium, as each firm would have an incentive to deviate. Hanes attributes the increase in nominal rigidity in the United States in the late 19th century to the rise of imperfect competition. There is a broad parallel with our model, in so far as the costs associated with strike action may be regarded as the menu cost of setting a lower nominal wage. Given the existence of such costs in Hanes's analysis, downward nominal rigidity only obtains when markets are imperfectly competitive, a result similar to that implied by our model.

Thirdly, there is the empirical evidence on the effects of monetary shocks. Using primarily

US data, various studies (for example, James Cover, 1992) have found that negative monetary shocks have a greater effect on output than positive ones. Several theoretical explanations have been suggested for this finding (see Magda Kandil, 1996), one being that it results from the Keynesian asymmetry. However, more recent work casts doubt on the robustness of Cover's results. Morten Ravn and Martin Sola (1996) find that, once the 1979 regime shift in monetary policy is allowed for, positive and negative shock have symmetric effects, a conclusion that is supported by Charles Weise (1999).[18] In conjunction with the micro data referred to above, which identify various patterns of asymmetric adjustments with no one type being prevalent, these recent findings highlighting a lack of asymmetry at the aggregate level are consistent with our general hypothesis that the pattern of nominal price adjustment depends on the market structures of the industries concerned.

IV. Conclusion

Although our analysis is intended as a depiction of one of the many forms that market competition may take, rather than to have general validity, we believe that, when combined with existing menu-cost formulations, it makes rather forcibly the point that the pattern of nominal price (in)flexibility induced by the presence of menu costs depends crucially on the type of competition assumed in the relevant markets. The fact that the Keynesian asymmetry does not appear in the two-period case, but is reversed in the more fiercely competitive infinite-horizon case, reinforces our conclusion.

Appendix

PROOF OF PROPOSITION 1.

We start from period *2.* For any given P_1^*, either $P_2^* = \hat{P}_2$, where $D(\hat{P}_2 / N_2)(\hat{P}_2 - N_2) = m N_2$, if price is adjusted, or $P_2^* = P_1^*$, if it is not.

(i) To prove that $P_1^* < \hat{P}_1$, suppose to the contrary that $P_1^* = \hat{P}_1$ (the argument holds *a fortiori* if $P_1^* > \hat{P}_1$). For this to be a Bertrand-Nash equilibrium, the incumbent must make no positive expected net profit in period *2*. Consider a realization $N_2 = N_1 + e$, with e positive and "small". Using (4), $p(\hat{P}_1 / N_2) < p(\hat{P}_1 / N_1) = m$, that is, no entrant could match (and *a fortiori* undercut) the incumbent's nominal price without incurring a real net loss. As $p(\cdot)$ is continuous in P_1, an appropriate e can be found such that $p(\hat{P}_1 / N_2) > 0$, so that the incumbent can maintain its period-*1* price and still make a positive real net profit. To prove that $N_1 < P_1^*$, suppose that $N_1 \geq P_1^*$, so that the incumbent not only would not be able to cover its menu cost but would make an additional real loss $D(P_1^* / N_1)(P_1^* / N_1 - 1) \leq 0$. This additional loss can never be recouped in period 2, where the maximum net real profit can be equal at most to the real menu cost *m*.

(ii): Two conditions must be satisfied for nominal price *not* to be adjusted in period *2:* (a) by retaining its period-*1* nominal price, the incumbent makes a non-negative real *gross* profit, and (b) no entrant can undercut period-*1* nominal price and make a non-negative *net* profit. Using (4), $\hat{N}_2 < N_1$, where $\hat{N}_2$ is defined by (6), and thus for any *negative* shock $N_2 \in [\hat{N}_2, N_1)$ no nominal price adjustment takes place. The largest *positive* shock that the incumbent would be

able to absorb without incurring a loss is determined by $D(P_1^* / N_2)(P_1^* - N_2) = 0$. This upper bound is P_1^*.

P_1^* is determined by the condition that the real net loss incurred in period 1 is offset by the discounted expected real net profit generated by nominal price rigidity in period 2, namely ,

$$\text{(A1)} \qquad m - D(\frac{P_1^*}{N_1})(\frac{P_1^*}{N_1} - 1) = d \int_{\hat{N}_2}^{P_1^*} D(\frac{P_1^*}{N_2})(\frac{P_1^*}{N_2} - 1)\, y(N_2)\, dN_2 .$$

where $d \leq 1$ is the discount factor.[19]

PROOF OF PROPOSITION 2.

Suppose firm f becomes the supplier for period t. Let $V^f(P_t / N_t)$ denote the expected present value of f 's real net profit stream from period t onwards, net of real menu cost m, when it prints a menu with nominal price P_t:

$$\text{(A2)} \qquad V^f(\frac{P_t}{N_t}; L_t, U_t) = \sum_{s=t+1}^{\infty} d^{s+1} \left[\int_{L_t}^{U_t} y(N)dN \right]^S p(\frac{P_t}{N_s}) - \left[m - p(\frac{P_t}{N_t}) \right]$$

where L_t and U_t are respectively the greatest lower and least upper bounds of the range of realizations of N for which the incumbent of period t can retain the previous period's nominal price, earn non-negative profits and not be undercut.[20]

Let P_1^* denote the lowest nominal price at which $V^f(P_1 / N_1; L_1, U_1) = 0$. Proposition 2(i) states that the equilibrium price P_1^* is such that in period 1 the price-setter makes a positive real gross profit (that is, $N_1 < P_1^*$) and a negative real net loss ($P_1^* < \hat{P}_1$).

(a) $N_1 < P_1^*$. Suppose to the contrary that $N_1 \geq P_1^*$. This implies that the non-positive real gross profit accruing in period 1 must be offset by strictly positive expected real net profits earned from period 2 onwards, that is, there must exist a range of realizations $[\hat{N}_2, P_1^*)$ such that

(A3) $$V^f(P_1^* / N_1; \hat{N}_2, P_1^*) = 0$$

To prove that no such range exists it suffices to show that for any $N_2 \in [\hat{N}_2, P_1^*)$, $V(P_1^* / N_2; \hat{N}_2, P_1^*) > 0$, so that undercutting by an entrant is both feasible and profitable. Using (A3) and (4) we obtain

(A4) $$V(P_1^* / N_2; \hat{N}_2, P_1^*) = p(P_1^* / N_2) - p(P_1^* / N_1) > 0 .$$

(b) $P_1^* < \hat{P}_1$. It cannot be the case that $P_1^* > \hat{P}_1$, because there can be no profitable hit-and-run entry in equilibrium. The remaining possibility $P_1^* = \hat{P}_1$ is ruled out by the fact that for all realizations of N_2 such that $N_1 < N_2 < \hat{P}_1$ firm f would make a strictly positive real net profit and could not be undercut, thereby implying that $V(P_1^* / N_1; N_1, P_1^*) > 0$ – a contradiction.

(ii). P_1^* is the smallest solution of the equation $V(P_1 / N_1; L_1, U_1) = 0$, that is

(A5) $$m - ð(P_1^* / N_1) = \sum_{s=2}^{\infty} ä^{s+1} \left[\int_{L_1}^{U_1} ø(N) dN \right]^S ð(P_1^* / N_s)$$

The l.h.s. of (A5) is the real net loss incurred at $t = 1$, whereas the r.h.s. of (A5) is the expected present value of the real net profit stream for $t = 2, \ldots, \infty$, conditional on *consecutive* realizations of N falling within the range where nominal price is kept unchanged, that is, $[L_1, U_1]$. We have already shown in Proposition 2(i) that charging P_1^* yields a real net loss in period 1 that has to be offset by retaining P_1^* as the ruling nominal price in period 2 for some realizations of N. All that remains to prove Proposition 2(ii) is to show that $L_1 = N_1$ and $U_1 = P_1^*$:

(a) $L_1 = N_1$. If $N_2 < N_1$, then at $t = 2$ the incumbent would be undercut, since other firms would face lower nominal costs than at $t = 1$ and thus the lowest nominal price such that $V(P_2 / N_2 ; L_2, U_2) = 0$ would be strictly less than P_1^*. If $N_2 = N_1$ the equilibrium price would stay unchanged. Therefore, $L_1 = N_1$.

(b) $U_1 = P_1^*$. For $N_2 > N_1$, no firm would find it profitable to undercut P_1^*. Thus U_1 is the realization of N at which the incumbent is indifferent between retaining P_1^* and making a new bid, which is P_1^* itself.

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Footnotes

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[1] For surveys, see N. Gregory Mankiw and David Romer (1991), Torben M. Andersen (1994) and Huw D. Dixon and Neil Rankin (1994).

[2] Models providing some support for the Keynesian asymmetry include Daniel Tsiddon (1993) and Laurence Ball and N. Gregory Mankiw (1994). However, Robert J Barro (1972) and N. Gregory Mankiw (1985), among others, produce two-directional stickiness. The Tsiddon and Ball-Mankiw models are based on the assumption of positive trend inflation, whereby a firm that wishes to reduce its relative price finds that it can do so costlessly merely by keeping its nominal price unchanged. Conversely, a firm that wishes to raise its relative price finds that inflation widens the gap between its desired and actual nominal price, thereby providing a strong incentive to incur a menu cost and raise its nominal price

[3] A similar pattern of greater downward flexibility is found in kinked-demand-curve models, but there it occurs essentially by assumption; see, for example, Jean Tirole (1988, pp. 243-44).

[4] A Bertrand duopoly model that yields the Keynesian asymmetry can be found in Per Svejstrup Hansen *et al*. (1996). Although their model and ours are not directly comparable (in so far as they consider *real* shocks and produce asymmetric price adjustments in the *absence* of menu costs), we conjecture that the opposite asymmetry generated by our model is due to our key assumption of free entry.

[5] To establish the basic message of the paper it is not necessary to examine the more complicated case of a T-period model, where $\infty > T > 2$.

[6] Where appropriate, we specify whether the model is of the two-period or of the infinite-horizon variety.

[7] If $J=1$ in our model nominal price adjusts in a manner similar to that found by Robert J. Barro (1972).

[8] The assumption of constant marginal cost merely simplifies the exposition, as our results would still hold if marginal cost were increasing (see footnote 14).

[9] As the product is assumed to be homogeneous, no benefits would flow from a long-term relationship and the agency always has the incentive to switch to a lower-price supplier. For example, in the UK, recurrent procurements of homogeneous goods for the National Health Service (amounting to about $1bn p.a.) are handled by the NHS Supply Agency on the basis of six-month contracts.

[10] Conversely, we assume that a menu printed in period t kills all older menus, that is, once a menu printed at t has been superseded by another menu in period $t + s$, it cannot be costlessly resurrected in later periods.

[11] The demand function is defined in terms of real prices only for simplicity. For more general demand functions of the form $D(P_t, N_t)$ we can identify simple conditions under which the main results apply (see footnote 14).

[12] Our results also apply with the more general demand function $D(P, N)$ if either (i) the elasticity of demand w.r.t. the nominal variable N weighted by the mark-up rate is less than unity (or, equivalently, menu costs are "small" compared to turnover); or (ii) the elasticity of demand w.r.t. changes in the nominal variable does not exceed the price elasticity of demand for output.

[13] Because firms are identical, except that one is incumbent in any period t, either $k = J$ or $k = 1$.

[14] As long as (4) is satisfied, our results still hold if marginal cost is not constant. Let the average real cost of production be $c[\,D(\,p_t\,)]$, where $c_D \geq 0$, so that $\pi(\,p_t\,) = D(\,p_t\,)\{\,p_t - c[\,D(\,p_t\,)]\}$. Therefore, $d\pi(\cdot)/dp_t = D_p\{\,p_t - c[\,D(\cdot)]\} + D(\cdot)\{1 - c_D D_p\,\}$. Hence, if (4) holds for $c_D = 0$, it holds *a fortiori* for $c_D > 0$. It is immaterial whether the reason for $c(\cdot)$ increasing is that there are diminishing returns in the production function or because the supply price of an input is increasing. Assumption 1, by guaranteeing that at any one time in equilibrium only one firm produces positive output, eliminates some of the potential complications associated with increasing marginal cost. The multiple-equilibria problem that plagues Bertrand competition is avoided (see Xavier Vives (1999), pp. 118-23); and the interdependence among firms' cost functions due to an increasing supply price of an input is absent by construction.

[15] Strictly speaking, the incumbent would earn non-negative real net profit because, for the single realization $N_2 = P_2^*$, real net profit would be zero (in this case we have assumed in Proposition 1 that the incumbent prefers retaining P_1^* to exiting).

[16] Notice that $\hat{N}_2 < N_1$. Suppose to the contrary that $\hat{N}_2 \geq N_1$; then, by (5) $\hat{P}_2 \geq \hat{P}_1 > P_1^*$ and so no entrant could *both* break even *and* match P_1^*.

[17] The condition specified in part (i) of the propositions – that in period 1 real net (gross) profits be negative (positive) – now applies not only to the first incumbent, but also to entrants in any period, that is, $P_t^* < \hat{P}_t \quad \forall t$.

[18] None the less, Weise confirms the result first obtained by Rene Garcia and Huntley Schaller (1995) that monetary policy changes have a stronger effect on output growth during recessions

than during booms.

[19] As formulated, Proposition 1 assumes that $\underline{N} \leq \hat{N}_2$ and $P_1^* \leq \overline{N}$, otherwise and somewhat trivially nominal price adjustment will be asymmetric by construction. In fact, if $P_1^* > \overline{N}$, then $P_2^* = P_1^*, \forall N_2 \in [\hat{N}_2, \overline{N}]$ and $P_2^* = \hat{P}_2 < P_1^*, \forall N_2 \in [\underline{N}, \hat{N}_2)$. Similarly, if $\hat{N}_2 < \underline{N}$, then $P_2^* = \hat{P}_2 > P_1^*, \forall N_2 \in (P_1^*, \overline{N}]$ and $P_2^* = P_1^*, \forall N_2 \in [\underline{N}, P_1^*]$.

[20] Notice that the probability that N_S falls within this range is raised to the power s to take into account *consecutive* draws in $[L_t, U_t]$.