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ARE PRICES TOO STICKY?

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ABSTRACT

This paper shows that small costs of changing nominal prices can lead to rigidities that cause highly inefficient fluctuations in real variables. As a result, aggregate demand stabilization can be very desirable even though the frictions that cause fluctuations in aggregate demand to have real effects are slight. Inefficient price rigidity arises because rigidity has a negative externality: rigidity in one firm's price increases the variability of real aggregate demand, which hurts all firms. The externality can be arbitrarily large relative to the private costs of rigidity.

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I. INTRODUCTION

According to Keynesian macroeconomics, nominal wages and prices are rigid. As a result, shocks to nominal aggregate demand cause large fluctuations in real variables such as employment and output. These fluctuations cause large welfare losses, and so stabilization of aggregate demand is highly desirable.

This view of the business cycle is often perceived as unsatisfactory because of the difficulty of explaining nominal rigidities. Microeconomics teaches us that nominal magnitudes are irrelevant to economic actors. Thus the only apparent impediments to flexibility of nominal prices are the costs of adjusting them--the costs of printing new menus, replacing price tags, and so on. These "menu" costs usually seem trivial compared to the welfare losses that Keynesians attribute to the business cycle. They are therefore generally viewed as not providing a basis for Keynesian theories.

This paper establishes that this view is not correct. We show that even very small costs of changing nominal prices can lead to rigidities that cause highly inefficient fluctuations in real variables. As a result, aggregate demand stabilization can be very desirable even though the frictions that cause fluctuations in aggregate demand to have real effects are slight.

To establish these results, we compare the gains to a firm from greater flexibility of its own price to the gains to society. The social gains are greater because price flexibility has a positive externality. The externality is Keynesian: increased flexibility of a firm's nominal price reduces the variability of real aggregate demand, which benefits all firms. The externality leads firms facing menu costs to choose excessive price stickiness, which in turn leads to excessively large economic fluctuations. Most important, we show that the reduction in average welfare that results from these fluctuations may be arbitrarily large relative to the private losses from rigidities. This implies that arbitrarily small menu costs can make nominal rigidities privately optimal even though the rigidities lead to large social losses.

Previous research has not addressed the issue of this paper. Investigations of the macroeconomic effects of menu costs (Mankiw, 1985; Akerlof and Yellen, 1985; Blanchard and Kiyotaki, 1985) have established the following. In an imperfectly competitive economy, the prices and quantities that are optimal for price setters are socially sub-optimal--specifically, prices are too high and output is too low. Therefore, starting from a private optimum, non-adjustment of prices to a nominal shock causes second order private losses but first order changes in social welfare. This implies that second order menu costs can lead firms to choose sticky prices even though the resulting fluctuations in welfare are first order. Crucially, the sign of the welfare effect of a nominal shock when prices are sticky depends on the sign of the shock. A negative shock, such as a fall in the money supply, causes welfare losses--prices are stuck too high, and so output is reduced. On the other hand, a positive shock causes welfare gains--output rises above the privately optimal level, and therefore is closer to the socially optimal level.

Since the welfare effects of rigidities are positive for some shocks and negative for others, the sign and magnitude of the effects on <u>average</u> welfare are not obvious. That is, it is not clear from previous work whether the economic fluctuations that result from menu costs are undesirable. As a result, it is also not clear whether, as Keynesians assert, it is desirable to reduce these fluctuations by stabilizing aggregate demand. In fact, we show that the first order effects of rigidities on welfare average to zero. Thus the first order/second order distinction that is central to previous work is irrelevant to the issue that we study. Our conclusion that small menu costs can lead to highly undesirable economic fluctuations depends on the relative sizes of private and social losses that are both second order.[1,2]

The remainder of the paper consists of four sections. Section II presents a macroeconomic model of a monopolistically competitive economy. The model is similar to the one in Blanchard and Kiyotaki. For simplicity, we assume that the economy consists of yeoman farmers who use their own labor to produce goods that they sell. Thus we suppress the labor market and focus on rigidities in output prices.

Sections III and IV compare the private and social costs of sticky prices. Section IV considers the natural case in which each farmer sets a price for his product and then, after a shock to aggregate demand, has the option of paying a menu cost and adjusting the price. This case is complicated, and so we start with a simpler one in Section III. In the simpler model, individuals must decide ex ante whether to pay the menu cost. In other words, a firm can either pay the menu cost, in which case it can costlessly adjust its price after the shock, or it can refuse to pay the menu cost, in which case it cannot change its price regardless of the size of the shock. Making the extent of price flexibility a zero-one variable simplifies the analysis considerably while still allowing us to investigate the private and social benefits of price flexibility.

In Section III, we calculate the ratio of the welfare losses from rigid prices to the size of the menu cost necessary to make rigidity an equilibrium. The ratio can be arbitrarily large. There is, however, a negative aspect of our results: the ratio is large only for a narrow range of parameter values. Therefore, while our simple model shows that small menu costs can in principle lead to large welfare losses, the welfare effects of menu costs in actual economies remain an open issue. Section IV establishes that the results of Section III carry over to the case in which firms choose whether to pay the menu cost after observing the nominal shock.

Finally, Section V compares our results with those in related papers, sketches extensions of our analysis, and offers conclusions.

II. THE MODEL

The economy consists of N producer-consumers, or "yeoman farmers." Each farmer uses his own labor to produce a differentiated product, then sells the product and uses the proceeds to purchase the products of all other farmers. Farmers take each others' prices as given.

Farmer i's utility function is

$$(1) \qquad U_i = C_i - \frac{\varepsilon - 1}{\gamma\varepsilon} L_i^{\gamma} - zD_i ,$$

where

$$(2) \qquad C_i = N\left[\frac{1}{N}\sum_{j=1}^{N} C_{ij}^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)}$$

and where:

- L_i is farmer i's labor supply;
- C_i is an index of farmer i's consumption;
- C_{ij} is farmer i's consumption of the product of farmer j;
- z is a small positive constant (the "menu cost");
- D_i is a dummy variable equal to one if farmer i changes his nominal price;
- ε is the elasticity of substitution between any two goods $(\varepsilon > 1)$;
- γ measures the extent of increasing marginal disutility of labor $(\gamma > 1)$.

(1) implies that farmers are risk neutral in consumption; we relax this assumption below. The coefficient on L_i^{γ} in (1) is chosen for convenience.

We assume that N is large, so that the contribution of good i to farmer i's utility is negligible. Finally, farmer i's production function is simply

$$(3) \qquad Y_i = L_i ,$$

where Y_i is farmer i's output.[3]

The utility function determines the demand for farmer i's product relative to aggregate consumption; specifically, one can show

$$(4) \qquad \frac{Y_i^D}{C} = \left(\frac{P_i}{P}\right)^{-\varepsilon} ,$$

where P_i is the price of good i and

$$(5) \qquad C = \frac{1}{N} \sum_{j=1}^{N} C_j ,$$

$$(6) \qquad P = \left[\frac{1}{N} \sum_{j=1}^{N} P_j^{1-\varepsilon}\right]^{1/(1-\varepsilon)} .$$

C is average consumption and P is the price index for the consumption basket: individual j must spend P to obtain one unit of C_j. Farmer i's consumption is determined by his real revenues:

$$(7) \qquad C_i = \frac{P_i Y_i}{P} .$$

(See Blanchard and Kiyotaki for a derivation of (4) - (7).) Substituting (3), (4), and (7) into (1) yields farmer i's utility as a function of aggregate consumption and his relative price:[4]

$$(8) \qquad U_i = C\left(\frac{P_i}{P}\right)^{1-\varepsilon} - \frac{\varepsilon - 1}{\gamma\varepsilon} C^{\gamma}\left(\frac{P_i}{P}\right)^{-\gamma\varepsilon} - zD_i .$$

To make nominal disturbances possible, we add a money market to the model. Specifically, we assume that money demand is given by the quantity equation, $M^d = PC$.[5] Letting M denote the money stock, the money market equilibrium condition is thus

$$\frac{M}{P} = C \,. \tag{9}$$

Substituting (9) into (8) yields farmer i's utility as a function of aggregate real money and his relative price:

$$U_i = \frac{M}{P}\left(\frac{P_i}{P}\right)^{(1-\varepsilon)} - \frac{\varepsilon - 1}{\gamma\varepsilon}\left(\frac{M}{P}\right)^{\gamma}\left(\frac{P_i}{P}\right)^{-\gamma\varepsilon} - zD_i \,. \tag{10}$$

Differentiation of (10) shows that farmer i's utility-maximizing price neglecting menu costs is

$$\frac{P_i^*}{P} = \left(\frac{M}{P}\right)^{\pi} , \tag{11}$$

$$\pi = \frac{\gamma - 1}{\gamma\varepsilon - \varepsilon + 1} , \quad 0 < \pi < 1.$$

Symmetric equilibrium occurs when $P_i = P$. Together with (1) - (11), this implies that the equilibrium prices and quantities in the absence of menu costs are $P_i = M$, $C_i = 1$, and $Y_i = 1$ for all i.

It proves convenient to rewrite the expression for utility, (10), as follows. Note that (11) implies

$$\frac{P_i}{P} = \frac{P_i}{P_i^*}\left(\frac{M}{P}\right)^{\pi} . \tag{12}$$

Substituting (12) into (10) gives farmer i's utility as a function of real balances, the ratio of his price to his utility-maximizing price, and the menu cost:

$$U_i = \left(\frac{M}{P}\right)^{\gamma(1-\varepsilon\pi)} \left[\left(\frac{P_i}{P_i^*}\right)^{(1-\varepsilon)} - \frac{\varepsilon - 1}{\gamma\varepsilon} \left(\frac{P_i}{P_i^*}\right)^{-\gamma\varepsilon} \right] - zD_i$$

(13)

$$\equiv V\left(\frac{M}{P}, \frac{P_i}{P_i^*}\right) - zD_i .$$

In what follows, we use (13) as our expression for utility.

III. THE PRIVATE AND SOCIAL COSTS OF NOMINAL PRICE RIGIDITY

We now introduce nominal disturbances by assuming that M is random. All farmers know the distribution of M.

In Section IV we assume that each individual sets his nominal price before M is realized and that he can change his price after observing M by paying the menu cost. In this section, we simplify the analysis by assuming that farmers must decide whether to pay the menu cost before M is realized. If a farmer does not pay the menu cost, he cannot change his nominal price ex post regardless of the realization of M; if he pays the menu cost, he can always change his price after he observes M.[6] Thus, each farmer has only two choices about the extent of nominal price flexibility: perfect flexibility or complete rigidity.

Our analysis proceeds in several steps. Part A determines the equilibrium price level when prices are sticky--that is, when they are set before M is known. Part B derives the condition for price stickiness to be an equilibrium. Stickiness is an equilibrium if, given that all other farmers choose stickiness, the menu cost is greater than the expected cost to farmer i of not adjusting his price. Part B finds this "private cost" of price rigidity. Part C derives the "social cost" of rigidity--the difference between farmer i's expected utility when all farmers choose flexibility and his expected utility when all choose rigidity. The social cost is greater than the private cost because rigidity has a negative externality: greater fluctuations in real aggregate demand. Part D shows that the ratio of the social cost to the private cost can be arbitrarily large. Thus small menu costs can cause rigidity to be an equilibrium even though flexibility would greatly improve welfare, and aggregate demand stabilization can be highly desirable. Part E discusses these results and describes how the ratio of social to private costs depends on the parameters of the model.

In both Sections III and IV we employ Taylor approximations, considering only terms in the mean and variance of M. For convenience, we normalize the mean of M to be one. Throughout, algebraic details are relegated to the Appendix.

A. The Price Level When Prices Are Sticky

We first derive the equilibrium price level when prices are sticky, P_0. The problem facing farmer i is to choose his price to maximize expected utility, $E\left[V\left(\frac{M}{P_0}, \frac{P_i}{P_i^*}\right)\right]$, taking P_0 as fixed. The first order condition is

$$(14) \qquad E\left[V_2\left(\frac{M}{P_0}, \frac{P_i}{P_i^*}\right) \frac{1}{P_i^*}\right] = 0 ,$$

where subscripts of V denote partial derivatives. Equation (12) gives P_i/P_i^* in terms of M/P_0 and P_i/P_0. A symmetric equilibrium requires $P_i = P_0$. Substituting these expressions into (14) implies that the equilibrium price level is given by

$$(15) \qquad E\left[V_2\left(\frac{M}{P_0}, \left(\frac{M}{P_0}\right)^{-\pi}\right)\left(\frac{M}{P_0}\right)^{-\pi}\right] = 0 .$$

Taking a second order Taylor approximation of (15) around $M/P_0 = 1$ (the equilibrium in the absence of menu costs) and using the fact that $E[M] = 1$, we find

$$\frac{1}{P_0} \cong 1 - \frac{\gamma}{2}\sigma_M^2 \tag{16}$$

(see the Appendix for details).

Equation (16) implies $P_0 > 1$. Since aggregate output equals M/P and since $E[M] = 1$, the mean level of output when prices are sticky is less than one, its level when prices are flexible. Farmers do not set $P_0 = E[M]$ (that is, certainty equivalence does not hold) because utility is not quadratic.[7] The effect of stickiness on mean output is not important for our results; they depend instead on the effect on the variance of output described below.[8]

B. When Is Price Stickiness an Equilibrium?

To see when sticky prices are an equilibrium, we compare farmer i's expected utility if he pays the menu cost with his expected utility if he does not, given that all other farmers do not. If farmer i does not pay the menu cost, then $D_i = 0$. $P_i = P_0$, as given by (16), since farmer i sets his price ex ante along with all other farmers. From (11), $P_i = P_0$ implies $P_i/P_i^* = (M/P)^{-\pi}$. Substituting this into (13) shows that farmer i's expected utility if he does not pay the menu cost is $E\left[V\left(\frac{M}{P_0}, \left(\frac{M}{P_0}\right)^{-\pi}\right)\right]$.

If farmer i pays the menu cost, then $D_i = 1$. Since farmer i adjusts his price ex post, he sets P_i equal to his utility-maximizing price for every realization of M. Thus $P_i/P_i^* \equiv 1$. The price level is still P_0, because farmer i is a small part of the economy and the other farmers do not pay the menu cost. Farmer i's expected utility is thus $E\left[V\left(\frac{M}{P_0}, 1\right)\right] - z$.

Stickiness is an equilibrium if farmer i's expected utility is lower when he pays the menu cost than when he does not. This is the case if

$$(17) \qquad E\left[V\left(\frac{M}{P_0}, 1\right)\right] - E\left[V\left(\frac{M}{P_0}, \left(\frac{M}{P_0}\right)^{-\pi}\right)\right] < z .$$

The left-hand side of (17) is the "private cost" of stickiness--the loss to farmer i from his inability to set P_i equal to P_i^* ex post. Stickiness is an equilibrium if this private cost is less than the menu cost.

As shown in the Appendix, expanding the formula for the private cost around $M/P_0 = 1$ leads to

$$(18) \qquad PC(\gamma,\varepsilon) \cong \frac{(\varepsilon-1)(\gamma-1)^2}{2[\gamma\varepsilon-\varepsilon+1]} \sigma_M^2 .$$

Since the private cost depends on σ_M^2, stickiness is an equilibrium if the menu cost is sufficiently large compared to the variance of money.

C. The Social Costs of Sticky Prices

This section computes the "social cost" of sticky prices--the difference between $V(\cdot)$ when all farmers pay the menu cost and when none pay the menu cost--and compares it with the private cost. If no farmer pays the menu cost, then, as shown in Section B, expected utility is $E\left[V\left(\frac{M}{P_0},\left(\frac{M}{P_0}\right)^{-\pi}\right)\right]$. If all farmers pay the menu cost, then $M/P = 1$ and $P_i/P_i^* = 1\ \forall i$ for all realizations of M . $V(\cdot)$ is therefore simply $V(1,1)$. The social cost of sticky prices--the amount that expected utility is reduced because prices do not adjust--is thus

$$(19) \qquad V(1,1) - E\left[V\left(\frac{M}{P_0},\left(\frac{M}{P_0}\right)^{-\pi}\right)\right] .$$

Comparison of (17) and (19) shows that the private and social costs of price stickiness differ. The social cost, (19), can be written as the sum of two terms:

$$(20) \qquad V(1,1) - E\left[V\left(\frac{M}{P_0},\ \left(\frac{M}{P_0}\right)^{-\pi}\right)\right]$$

$$= \left[E\left[V\left(\frac{M}{P_0},1\right)\right] - E\left[V\left(\frac{M}{P_0},\ \left(\frac{M}{P_0}\right)^{-\pi}\right)\right]\right]$$

$$+ \left[V(1,1) - E\left[V\left(\frac{M}{P_0},\ 1\right)\right]\right] .$$

The first term is the private cost of stickiness (see (17)). The second is the "externality" from stickiness. This externality is the gain to a farmer from stabilization of real money, and hence real aggregate demand. Price flexibility stabilizes real money, but each farmer ignores this public benefit when deciding whether to pay the menu cost. The social cost of rigidity is the sum of the private cost and the externality.

The private cost is given by (18). The externality can be approximated as (see Appendix)

(21) $$EX(\gamma,\varepsilon) \cong \frac{\gamma^2\varepsilon - \varepsilon + 1}{2\varepsilon[\gamma\varepsilon - \varepsilon + 1]} \sigma_M^2 .$$

Like the private cost, the externality is proportional to σ_M^2 -- that is, it is second order. The first order gains and losses from fluctuations in real money average to zero.

D. Comparing the Private and Social Costs

Combining (18) and (21), the ratio of the social cost of price stickiness to the private cost is

(22) $$\begin{aligned} R(\gamma,\varepsilon) &= \frac{PC(\gamma,\varepsilon) + EX(\gamma,\varepsilon)}{PC(\gamma,\varepsilon)} \\ &\cong \frac{(\varepsilon\gamma - \varepsilon + 1)^2}{\varepsilon(\varepsilon-1)(\gamma-1)^2} \\ &= \left[\frac{\varepsilon\gamma + 1 - \varepsilon}{\varepsilon\gamma - \varepsilon}\right]\left[\frac{\varepsilon\gamma + 1 - \varepsilon}{\varepsilon\gamma + 1 - \varepsilon - \gamma}\right] . \end{aligned}$$

To interpret R, recall that rigidity is an equilibrium as long as the private cost does not exceed z. Thus the largest possible social cost of farmers' choice of rigidity is Rz. In addition, note that stabilization of aggregate demand -- $\sigma_M^2 = 0$ -- eliminates the losses from rigidity (both the private cost and the externality are proportional to σ_M^2). Thus Rz is also the maximum possible welfare gain from stabilizing demand.[9]

Expression (22) is greater than one. Thus the social cost of price rigidity is greater than the private cost. More important, as either ε or γ approaches one, R approaches infinity. The ratio of the social cost to the private cost can be arbitrarily large. As a result, Rz can be large even if z is very small. A small menu cost can lead to rigidities that cause large reductions in average welfare, and aggregate demand stabilization can be highly beneficial.[10]

E. Discussion

We summarize our analysis as follows. A farmer's expected utility depends on two factors: how close on average his relative price is to the utility-maximizing level (P_i/P_i^*), and the distribution of real aggregate demand (M/P). In deciding whether to pay the menu cost each farmer takes the distribution of aggregate demand as given and considers only the gains from charging the utility-maximizing price. He ignores the fact that flexibility of his price helps to stabilize aggregate demand, which benefits all farmers. Thus the externality from price rigidity is Keynesian. Our results show that the externality can be large compared to the private cost of rigidity.[11]

We now describe how the parameters of the model affect the ratio of the social to the private costs of rigidity. Differentiation of (22) shows that R is decreasing in ε, the elasticity of demand for an individual farmer's output. The source of this result is twofold. First, when product demand is highly elastic the consequences of setting P_i not equal to P_i^* are large; thus the private cost of rigidity is increasing in ε. Second, the more competitive are product markets, the less relevant is aggregate demand to an individual seller; thus the externality is decreasing in ε. As ε approaches infinity--that is, as the product market approaches perfect competition--the externality converges to zero while the private cost remains strictly positive, and so R approaches one. As ε approaches one, the private cost approaches zero, and so R approaches infinity.

Differentiation of (22) shows that γ affects R ambiguously. This occurs because a large value of γ --that is, quickly increasing marginal disutility of labor--implies that both the private cost of rigidity and the externality are large $(\partial PC(\varepsilon,\gamma)/\partial\gamma > 0$, $\partial EX(\varepsilon,\gamma)/\partial\gamma > 0)$. Both departures of a farmer's price from P_i^* (the private cost) and fluctuations in aggregate demand (the externality) increase fluctuations in output. When γ is large, these fluctuations are very costly. Thus a change in parameters that makes fluctuations more undesirable does <u>not</u> necessarily increase the losses caused by small menu costs. The reason is that such a change may make farmers more likely to pay the menu cost.

Although $\partial R(\varepsilon,\gamma)/\partial\gamma$ is ambiguous, $\lim_{\gamma\to 1} R(\varepsilon,\gamma) = \infty$. As γ approaches one, π approaches zero--that is, P_i^*/P approaches one for all values of M/P . It follows that if other farmers' prices are sticky, a given farmer has little incentive to change his price regardless of the realization of M ; hence the private cost of non-adjustment approaches zero. The externality remains strictly positive, and so the ratio of social to private costs approaches infinity.[12]

A slight modification of the model allows us to investigate the effects of risk aversion in consumption. Modify the utility function, (1), to be

$$U_i = \frac{1}{\alpha} C_i^{\alpha} - \frac{\varepsilon-1}{\gamma\varepsilon} L_i^{\gamma} - zD_i \,, \qquad (23)$$

where α is one minus the coefficient of relative risk aversion $(\alpha \leq 1)$.

With this change, one can show that the ratio of the social to the private cost of rigidity is

$$(24) \qquad R(\varepsilon,\gamma,\alpha) \cong \frac{[\varepsilon\gamma - (\varepsilon-1)\alpha]^2}{\varepsilon(\varepsilon-1)\ (\gamma-\alpha)^2}$$

(see the Appendix). Perhaps surprisingly, $\partial R(\varepsilon,\gamma,\alpha)/\partial\alpha$ is ambiguous. Thus risk aversion in consumption does not strengthen the argument that the fluctuations resulting from menu costs are undesirable. The explanation for this result is similar to the explanation for the role of γ : risk aversion increases both the private cost of rigidity and the externality. Risk aversion implies that fluctuations in real aggregate demand are very costly to a farmer. But it also means that the farmer is very eager to adjust his relative price to minimize the effects of the fluctuations on his consumption.[13]

There is one important negative aspect of our results: while the ratio of social to private costs of rigidity is unbounded, it is large only for a narrow range of parameters. To see this, suppose that farmers are risk neutral in consumption and that $\varepsilon = 5$ (which implies price 25% above marginal cost) and $\gamma = 5$ (equivalent to an intertemporal labor supply elasticity of 1/4). For these plausible parameters, $R = 1.4$ --the social costs of rigid prices are not much larger than the private costs. As noted above, values of ε or γ close to one are necessary for R to be large. However, even $\varepsilon = 2$ (a markup of 100%) and $\gamma = 2$ (a labor supply elasticity of 1) produce an R of only 4.5. For these parameters, the welfare losses from the business cycle are only four and a half times the cost of printing new menus for all farmers. R is large only if ε or γ is very close to one. For example, $\varepsilon = 2$, $\gamma = 1.1$ implies $R = 72$.

Thus we have demonstrated that price rigidity has externalities and that, in principle, they can be very large. In our model, however, the externalities are <u>not</u> large for reasonable parameter values. The model is very simple--aside from the menu cost, our only departure from Walrasian general equilibrium theory is the assumption of monopolistic competition. An open and important research question is whether realistic modifications of our model can produce a formula for R that is large for plausible parameters.

A natural possibility to consider would be the introduction of imperfections in the labor market. In our model, R is affected by how quickly the marginal disutility of labor increases, which is equivalent to a labor supply elasticity. Empirical evidence suggests that labor supply is not very elastic--that is, that γ is not close to one--and this implies that the private costs of rigidity are large for plausible values of ε. If the labor market does not clear (as in efficiency wage models, for example) then labor supply may be unimportant to firms; thus a large γ might not imply large private costs of rigidity of firms' prices.

IV. THE CASE OF EX POST DECISIONS CONCERNING WHETHER TO PAY THE MENU COST

This section considers the case in which individuals can wait until they observe the money supply before deciding whether to pay the menu cost. We first solve for the range of shocks over which non-adjustment is an equilibrium. Then we solve for the social costs of non-adjustment over this range. As in Section III, we find that arbitrarily small menu costs can lead to rigidities that cause large welfare losses.

We simplify the analysis by placing restrictions on the distribution of M. We assume that the distribution is continuous, symmetric around one, increasing for $M < 1$, and decreasing for $M > 1$.[14] As in Section III, we consider only symmetric equilibria, and we use second order approximations throughout.

The first step is to solve for the price that farmers set before they observe the money supply. This price is relevant only if the money supply falls in the range over which farmers do not adjust prices ex post. Let $\hat{\sigma}_M^2$ be the variance of M conditional on M lying in this range and assume that the conditional mean of M is one (this assumption is justified below). By the reasoning in Section III.A, the price that farmers set ex ante is given by

$$(25) \qquad \frac{1}{P_0} \cong 1 - \frac{\gamma}{2}\hat{\sigma}_M^2 .$$

We next determine the range of shocks over which price stickiness is an equilibrium. For a given M, we compare farmer i's utility if he pays the menu cost and if he does not, assuming that other farmers do not. By reasoning similar to that of Section III.B, farmer i's utility if he pays the menu cost is $V\left(M/P_0, 1\right) - z$. His utility if he does not pay is $V\left(M/P_0, \left(M/P_0\right)^{-\pi}\right)$. Thus farmer i pays the menu cost for values of M such that

$$(26) \qquad V\left(M/P_0\,,\, 1\right) - V\left(\frac{M}{P_0}\,,\, \left(\frac{M}{P_0}\right)^{-\pi}\right) < z\,.$$

As shown in the Appendix,

$$(27) \qquad V\left(\frac{M}{P_0}, 1\right) - V\left(\frac{M}{P_0}\,,\, \left(\frac{M}{P_0}\right)^{-\pi}\right) \approx \frac{(\varepsilon-1)(\gamma-1)^2}{2[\gamma\varepsilon-\varepsilon+1]} (M-1)^2\,.$$

Since the private cost of non-adjustment is proportional to $(M-1)^2$, farmer i chooses not to pay the menu cost for realizations of M in a range centered at one. (Since the distribution of M is symmetric around 1, this justifies the assumption made above concerning the conditional mean of M.) Let the range be $(1-x, 1+x)$. The endpoints are the values of M at which farmer i is indifferent about paying the menu cost. Thus x is defined by

$$(28) \qquad \frac{(\varepsilon-1)(\gamma-1)^2}{2[\gamma\varepsilon-\varepsilon+1]} x^2 = z\,;$$

$$(29) \qquad x = \sqrt{\frac{2[\gamma\varepsilon-\varepsilon+1]z}{(\varepsilon-1)\ (\gamma-1)^2}}$$

Now we determine the social cost of equilibrium stickiness. That is, we compare $E[V(.)]$ if all prices are perfectly flexible to $E[V(.)]$ if prices adjust only when M is outside of $(1-x, 1+x)$. If M falls outside

(1-x,1+x) , the difference in V(.) is zero. If M falls within (1-x,1+x) , the difference is

(30) $$V(1,1) \; - \; V\left[\frac{M}{P_0}, \left[\frac{M}{P_0}\right]^{-\pi}\right] .$$

Given these results about the loss for each realization of M , the social cost is

(31) $$\int_{M=1-x}^{M=1+x} \left[V(1,1) \; - \; V\left[\frac{M}{P_0}, \left[\frac{M}{P_0}\right]^{-\pi}\right]\right] f(M)dM ,$$

where f(.) is the density function for M. The social cost can be approximated by

(32) $$[F(1+x) - F(1-x)][\frac{\gamma\varepsilon-\varepsilon+1}{2\varepsilon}]\hat{\sigma}_M^2 ,$$

where F(.) is the cumulative distribution function of M (see the Appendix).

Combining (28) and (32) shows that the ratio of the social cost of price rigidity to the menu cost that causes it is

(33) $$\frac{\hat{\sigma}_M^2}{x^2} [F(1+x) \; - \; F(1-x)] \; R ,$$

where R is again given by (22). $\hat{\sigma}_M^2$ is the expected value of $(M-1)^2$ conditional on $(M-1)^2 \leq x^2$, and so $\hat{\sigma}_M^2/x^2$ lies between 0 and 1. It depends on the distribution of M and on (29), which determines x . (If M has a uniform distribution with endpoints outside of (1+x,1-x) , then $\hat{\sigma}_M^2/x^2 = 1/3$.) F(1+x) - F(1-x) also lies between 0 and 1 and depends on the distribution of M and on x . For any ε and γ ,

$(\hat{\sigma}_M^2/x^2)[F(1+x) - F(1-x)]$ can be arbitrarily close to one. Since R can be arbitrarily large, it follows that the ratio in (33) can be arbitrarily large. Thus, the finding of the previous section that small nominal frictions can cause large reductions in average welfare carries over to the case in which farmers decide ex post whether to pay the menu cost.

In general, the effects of the parameters on the ratio of the losses from rigidity to z are more complicated than in Section III because the parameters affect all three terms in (33). We omit further discussion of this issue.

V. DISCUSSION AND CONCLUSIONS

A. Comparison to Previous Literature

Previous work has established that small menu costs can lead to rigidities that cause large fluctuations in welfare. Specifically, in the presence of menu costs, positive shocks to nominal aggregate demand can cause large welfare gains and negative shocks can cause large losses. This paper establishes that rigidities due to menu costs can lead to large reductions in average welfare. Keynesians believe not only that welfare fluctuates greatly over the business cycle, but also that it would be highly desirable to reduce the magnitude of fluctuations, for example by stabilizing nominal aggregate demand. Thus our result is crucial to the role of small menu cost models in the micro foundations of Keynesian macroeconomics.

The source of our results is very different from the source of previous menu cost results. The externalities identified by previous authors arise because the privately optimal level of output is lower than the socially optimal level in a monopolistically competitive economy. This divergence between equilibrium and optimal output means that non-adjustment of prices to a nominal shock causes second order private losses but first order social losses (or gains). In contrast, price rigidity has externalities in our model because it increases fluctuations in real aggregate demand, which hurts all individuals. The externality is second order, but it may be much larger than the private cost of price rigidity.

We illustrate the difference between the source of our results and the source of previous results by considering the effects of a government subsidy to production that raises equilibrium output to the optimal level. Specifically, suppose that farmer i receives $P_i\left(\frac{\varepsilon}{\varepsilon - 1}\right)$ for each unit of his output that he sells, with the subsidy financed by lump sum taxes. In this situation equilibrium output in the absence of shocks is

$$(34) \qquad Y_i = \left(\frac{\varepsilon}{\varepsilon - 1}\right)^{1/(\gamma-1)} ,$$

which is first best. With this modification of the model, the welfare results of previous menu cost papers no longer hold--since equilibrium output is optimal, both private and social losses from non-adjustment to a shock are second order. In contrast, the argument of this paper is essentially unchanged. Analysis along the lines of Parts A-D of Section III, using approximations around $\frac{M}{P} = \left(\frac{\varepsilon}{\varepsilon - 1}\right)^{1/(\gamma-1)}$ and $P_i/P_i^* = 1$ shows that in the presence of the subsidy the ratio of the social to the private costs of price stickiness is

$$(35) \qquad R^*(\gamma,\varepsilon) \cong \frac{\gamma\varepsilon - \varepsilon + 1}{\varepsilon(\gamma-1)} .$$

$R^*(\gamma,\varepsilon)$ can be arbitrarily large. Thus our result that small frictions can cause large reductions in average welfare does not depend on the fact that equilibrium output is too low under monopolistic competition.

While our results are very different from the ones in previous menu cost models, they are similar in some respects to Ball's (1986a) results about externalities from the length of labor contracts. Ball shows that an increase in the length of a firm's contract contributes to slow adjustment of the wage level, and hence of the price level, to monetary shocks. This leads to larger fluctuations in real aggregate demand, which hurts all firms. This is similar to the externality from price rigidity in the current paper.[15]

Our analysis differs from Ball's in two important respects. First, and most important, Ball addresses only the issue of whether there are externalities from rigidity while we consider the size of the externalities. Second, in Ball's model, wage rigidity has a <u>positive</u> externality that has no analogue in the current paper--an improvement in the forecastability of the future price level, which helps all firms. The net effect of the positive and negative externalities is ambiguous.[16]

The difference between our results and Ball's arises from the following. In our model, the externality is a firm's loss from the rigidity of other firms' prices conditional on <u>flexibility</u> of its own price (that is, conditional on $P_i = P_i^*$; see equation (20)). In Ball, a firm sets its wages in a long-term contract. Thus the externalities from other firms' contract lengths are the externalities conditional on the firm's own wage being <u>rigid</u>. This creates the positive externalities from rigidity that do not exist in the current model; intuitively, a firm may dislike flexibility in other firms' wages if it is unable to adjust its own wage in response to changes in theirs.

B. Extensions

This section sketches two extensions of our model. First, we consider costs of adjusting output. In actual economies these appear to be large compared to menu costs, and they increase firms' incentives to stabilize output by adjusting prices. We modify equation (1) as follows:

$$U_i = C_i - \frac{\varepsilon-1}{\gamma\varepsilon} L_i^{\gamma} - zD_i - G(Y_i - 1) , \tag{36}$$

where $G(\cdot)$ is the cost of changing output from one, its level in the absence of shocks; we assume $G(0) = G'(0) = 0$ and $G''(.) > 0$.

Using the production function, $Y_i = L_i$, (36) can be rewritten as

$$(37) \quad U_i = C_i - \frac{\varepsilon-1}{\gamma\varepsilon} Y_i^\gamma - G(Y_i - 1) - zD_i .$$

Thus adding costs of adjusting quantities means adding $G(\cdot)$ to the utility loss from producing output Y_i . This implies that the change is equivalent to raising the degree of increasing marginal disutility of labor (γ) or introducing diminishing returns in production. It would therefore not affect our central results. In particular, there would be no new externality from rigidity in quantities. Indeed, it is likely that adding costs of changing output would have an ambiguous effect on the ratio of social to private costs of price rigidity. Like a high value of γ or strong risk aversion in consumption, large costs of quantity adjustment would raise both the numerator and the denominator of R .

Our second extension is adding the Mundell effect. The externality from nominal rigidities in our model is increased fluctuations in real aggregate demand. Recent work by DeLong and Summers (1986a, b) shows, however, that marginal increases in rigidity may reduce these fluctuations because they reduce the variance of expected inflation.

Letting aggregate demand depend on expected inflation would not change our central results. Each farmer ignores his effects on expected inflation (as well as the externality that we emphasize), and so the equilibrium degree of rigidity would be unaffected. In addition, while the externality from a <u>marginal</u> change in rigidity would be ambiguous, the effect of full flexibility would not--even with the Mundell effect, it would raise welfare by eliminating all fluctuations arising from nominal shocks. Thus the welfare effects of the menu costs that prevent full flexibility would still be unambiguously negative and possibly large. Our central policy result would also be unchanged. The welfare losses from rigidity would still be increasing in the variance of nominal money and zero for $\sigma_M^2 = 0$, and so stabilization of nominal demand would still be desirable.

On the other hand, at least one implication of our model might change if we added a Mundell effect. We find that the loss from equilibrium rigidity is increasing in z --for example, in Section III, the maximum loss is Rz . Thus a marginal reduction in z (for example through a subsidy to price changes) and the resulting decrease in rigidity would reduce the loss. The Mundell effect might reverse this result for some values of z .

C. Conclusions

Keynesians argue that rigidities in nominal wages and prices lead to large fluctuations in real variables in response to nominal shocks. These fluctuations cause large welfare losses, and so it is highly desirable to reduce them--for example, by stabilizing aggregate demand. These ideas are generally viewed as having weak microeconomic foundations, because the costs of adjusting wages and prices usually appear small. This paper shows that this reasoning is not valid. Price rigidity has a negative externality: rigidity in a firm's price increases fluctuations in real aggregate demand, which hurts all firms. This externality can be very large. Therefore, very small costs of changing prices can lead firms to choose rigidity even though the resulting economic fluctuations cause large welfare losses.

Our results do not, however, provide a complete defense of the traditional Keynesian view. In our model, the externality from price rigidity is large only over a narrow and implausible range of parameter values. Thus we show that the externality can be large in principle, but not that it is large in practice. Future research should investigate whether realistic modifications of our model, such as the introduction of additional imperfections, imply that the externalities from rigidity are large for reasonable parameter values.

APPENDIX

<u>Derivation of (16)</u>. Taking a second-order approximation of (15) around $M/P_0 = 1$ and simplifying the result yields

$$\text{(A1)}\quad -V_{22}E\left[\frac{M}{P_0} - 1\right] + \frac{1}{2}\left[(3\pi+1)V_{22} - 2V_{212} + \pi V_{222}\right]E\left[\left(\frac{M}{P_0} - 1\right)^2\right] = 0 ,$$

where all partial derivatives are evaluated at $(1,1)$. (A1) incorporates the fact that $V_2(1,1) = V_{21}(1,1) = V_{211}(1,1) = 0$ because $V_2\left(\frac{M}{P},1\right) = 0$ for all M/P. Using $E[M] = 1$ and $E\left[\left(\frac{M}{P} - 1\right)^2\right] = \left(E\left[\frac{M}{P} - 1\right]\right)^2 + \mathrm{Var}\left(\frac{M}{P} - 1\right)$, (A1) can be rewritten as

$$\text{(A2)}\quad -V_{22}\left(\frac{1}{P_0} - 1\right) + \frac{1}{2}\left[(3\pi+1)V_{22} - 2V_{212} + \pi V_{222}\right]\left[\left(\frac{1}{P_0} - 1\right)^2 + \frac{\sigma_M^2}{P_0^2}\right] = 0 .$$

(A2) defines $1/P_0$ as a function of σ_M^2. Implicit differentiation gives

$$\text{(A3)}\qquad \frac{1}{P_0} \cong 1 + \frac{(3\pi+1)V_{22} - 2V_{212} + \pi V_{222}}{2V_{22}}\sigma_M^2 ,$$

where we neglect terms in $(\sigma_M^2)^2$. Computing the appropriate partial derivatives of $V(.)$, substituting into (A3), and simplifying yields (16).

<u>Derivation of (18)</u>. Expanding the formula for the private cost around $M/P_0 = 1$ yields

$$\text{(A4)} \qquad PC \cong -\frac{\pi^2}{2} V_{22}\, E\left[\left(\frac{M}{P_0} - 1\right)^2\right]$$

$$\cong -\frac{\pi^2}{2} V_{22}\, \sigma_M^2 \ ,$$

where partial derivatives are again evaluated at $(1,1)$. The first line incorporates the fact that $V_2(1,1) = V_{12}(1,1) = 0$ and the second line the fact that (using (A3))

$$\text{(A5)} \quad E\left[\left(\frac{M}{P_0} - 1\right)^2\right] = \left(E\left[\frac{M}{P_0} - 1\right]\right)^2 + \mathrm{Var}\left(\frac{M}{P_0} - 1\right)$$

$$= \left(\frac{1}{P_0} - 1\right)^2 + \frac{\sigma_M^2}{P_0^2}$$

$$\cong \sigma_M^2 \ ,$$

where we again neglect terms in $(\sigma_M^2)^2$. Substituting the expression for $V_{22}(1,1)$ into (A4) yields (18).

Derivation of (21). Expanding the expression for the externality around $M/P_0 = 1$ yields

$$\text{(A6)} \quad \begin{aligned} EX &\cong -V_1 E\left[\frac{M}{P_0} - 1\right] - \frac{1}{2} V_{11} E\left[\left(\frac{M}{P_0} - 1\right)^2\right] \\ &\cong -V_1\left[\frac{(3\pi+1)V_{22} - 2V_{212} + \pi V_{222}}{2V_{22}}\, \sigma_M^2\right] - \frac{1}{2} V_{11}\sigma_M^2 \ . \end{aligned}$$

The first line uses $V_{12}(1,1) = 0$ and the second uses (A3) and (A5). Substituting the appropriate partial derivatives yields (21).

Derivation of (24). Replace (1) with (23). By reasoning similar to that of Section II, one can derive the following generalizations of (11) and (13):

$$\text{(A7)} \qquad \frac{P_i^*}{P} = \left(\frac{M}{P}\right)^{\pi}, \quad \pi = \frac{\gamma-\alpha}{\gamma\varepsilon-\alpha\varepsilon+\alpha};$$

$$\text{(A8)} \qquad V\left(\frac{M}{P}, \frac{P_i}{P_i^*}\right) = \left(\frac{M}{P}\right)^{\gamma(1-\varepsilon\pi)} \left[\frac{1}{\alpha}\left(\frac{P_i}{P_i^*}\right)^{(1-\varepsilon)\alpha} - \frac{\varepsilon-1}{\gamma\varepsilon}\left(\frac{P_i}{P_i^*}\right)^{-\gamma\varepsilon}\right] - zD_i .$$

With these redefinitions of π and $V(.)$, the expressions for the private cost and the externality given by (A4) and (A6) remain valid. Substituting the new π and the partial derivatives of the new $V(.)$ into (A4) and (A6) yields

$$\text{(A9)} \qquad PC(\varepsilon,\gamma,\alpha) \cong \frac{(\varepsilon-1)\ (\gamma-\alpha)^2}{2[\gamma\varepsilon-(\varepsilon-1)\alpha]}\ \sigma_M^2 ,$$

$$\text{(A10)} \qquad EX(\varepsilon,\gamma,\alpha) \cong \frac{\gamma^2\varepsilon - \alpha^2(\varepsilon-1)}{2\varepsilon[\gamma\varepsilon - (\varepsilon-1)\alpha]}\ \sigma_M^2 .$$

(24) follows from (A9) and (A10).

Derivation of (27). By reasoning similar to that used to derive (A4),

$$\text{(A11)} \quad V\left(\frac{M}{P_0},1\right) - V\left(\frac{M}{P_0}, \left(\frac{M}{P_0}\right)^{-\pi}\right) \cong -\frac{\pi^2}{2} V_{22}\left(\frac{M}{P_0} - 1\right)^2$$

$$\cong -\frac{\pi^2}{2} V_{22}(M-1)^2.$$

Substituting the expression for $V_{22}(1,1)$ yields (27).

Derivation of (32). Using approximations similar to (A4) and (A6),

$$\text{(A12)} \quad \int_{M=1-x}^{1+x} \left[V(1,1) - V\left(\frac{M}{P_0}, \left(\frac{M}{P_0}\right)^{-\pi}\right)\right] f(M)dM$$

$$\cong \int_{M=1-x}^{1+x} \left[- V_1\left(\frac{M}{P_0} - 1\right) - \frac{1}{2}\left(V_{11} + \pi^2 V_{22}\right)\left(\frac{M}{P_0} - 1\right)^2\right] f(M)dM$$

$$= [F(1+x) - F(1-x)]\left[-V_1 E\left[\frac{M}{P_0} - 1 \,\middle|\, 1-x<M<1+x\right] - \frac{1}{2}(V_{11}+\pi^2 V_{22}) E\left[\left(\frac{M}{P_0} - 1\right)^2 \,\middle|\, 1-x<M<1+x\right]\right]$$

$$\cong [F(1+x) - F(1-x)]\left[- V_1 \frac{(3\pi+1)V_{22} - 2V_{212} + \pi V_{222}}{2V_{22}} - \frac{1}{2}(V_{11}+\pi^2 V_{22})\right]\hat{\sigma}_M^2 .$$

Substituting the appropriate partial derivatives yields (32).

NOTES

1. Mankiw claims to establish that "sticky prices can be both privately efficient and socially inefficient. . . . To the extent that policy can stabilize aggregate demand, it can mitigate the social loss due to . . . suboptimal adjustment [of prices]. Small menu costs can cause large welfare losses." In fact, Mankiw shows that stickiness arising from menu costs can cause large welfare losses when demand falls and large welfare gains when demand rises. In other words, after a positive shock price flexibility can be privately efficient but socially inefficient. Mankiw does not ask how menu costs or demand stabilization affect average welfare.

2. Our result is closer in spirit to the result of Ball (1986a) that externalities from nominal wage rigidity may cause the equilibrium length of labor contracts to exceed the socially optimal length. We discuss the relation between our model and Ball's in the conclusion. Schultze (1985), Weitzman (1985, 1986), and Taylor (1985) suggest informally that nominal rigidities have negative externalities.

3. The model would be essentially unchanged if we assumed instead that the marginal disutility of labor is constant and that production has diminishing returns.

4. If a farmer's price is rigid and aggregate demand rises by a large amount, the farmer may wish to ration purchasers of his product. (8) ignores this possibility. However, because the farmer does not wish to ration after a small shock (since price exceeds marginal cost before the shock), and because the analysis below employs Taylor approximations around the no-shock equilibrium, our results would not change if we modified (8) to account for rationing.

5. Our results would not change if, following Blanchard and Kiyotaki, we made real balances an argument of the utility function rather than specifying money demand directly. Our approach is simpler.

6. In this version of the model, the "menu cost" could be interpreted as an "indexing cost" -- a cost of making price a function of M.

7. This deviation from certainty equivalence is similar to the effect of non-quadratic utility in models of optimal consumption and saving (see Zeldes, 1986). Kuran (1985) presents another model in which nominal rigidity affects mean output because utility is not quadratic.

8. Our qualitative results would not change if we simply imposed $P_0 = 1$. Alternatively, if production is subsidized so that the no-shock level of output is first best (an experiment discussed in Section V), the welfare effects of changes in mean output disappear by the envelope theorem but our main results are unaffected.

9. It is straightforward to modify the model by adding a velocity disturbance to money demand. In this case, Rz is the maximum possible gain from using monetary policy to offset velocity shocks.

10. An alternative way of deriving R is to begin by writing utility as a function of P_i/P and M/P rather than P_i/P_i^* and M/P (see equation (10)): $U_i = W(M/P, P_i/P) - zD_i$. Analysis parallel to that of Sections A-D then yields

$$(22') \quad R \cong \frac{W_{11}W_{12}W_{22} - W_1W_{22}W_{211}}{W_{12}^3},$$

where all partial derivatives are evaluated at $(1,1)$. Substituting the appropriate derivatives of (10) into (22') gives (22). (22') holds generally; it does not depend on the specifics in (10). Thus it is possible to use (22') to compute the ratio of the social to the private cost of stickiness for different utility functions and for different assumptions about the structure of the economy.

11. The result that the private and social costs of price rigidity differ is a specific instance of Greenwald and Stiglitz's (1986) finding that pecuniary externalities can lead to Pareto inefficiency if a distortion exists. The distortion in the model is imperfect competition.

12. While we emphasize the effect of rigidity on the variance of real money in our discussion of the effects of the parameters, some details of those effects depend on how rigidity influences the mean of real money (see Section III.A). In particular, if we ignore the effect on the mean (for example by imposing $P_0 = 1$), then $\partial R(\varepsilon,\gamma)/\partial\varepsilon$ remains negative but $\lim_{\varepsilon\to 1} R(\varepsilon,\gamma)$ equals $\gamma/(\gamma-1)$ rather than infinity. In addition, while it is still the case that $\lim_{\gamma\to 1} R(\varepsilon,\gamma) = \infty$, the explanation is slightly different: both the private cost and the externality approach zero as γ approaches one, but the private cost approaches zero more quickly.

13. When farmers are risk averse, R can be less than one--there can be a positive externality from price stickiness. This possibility arises because with risk aversion P_0 may be less than one, and so stickiness may raise the mean of output (see Section III.A). For some parameter values, the gains from higher mean output outweigh the losses from greater variance of output.

14. Allowing peculiarities in the distribution of M would complicate the analysis considerably. For example, suppose that the money stock could take on only two values, M_a and M_b, each with probability one-half. Then there may be two equilibria, one in which farmers set their prices equal to M_a and pay the menu cost if $M = M_b$ and one in which they do the reverse.

15. A firm's choice of whether to index its wage to the aggregate price level also has a similar externality (Ball, 1986b).

16. The roles of the parameters are also different in the two models. For example, a large labor supply elasticity makes it likely that rigidity has a positive externality in Ball's model; in the current paper, elastic labor supply (γ close to one) implies a large negative externality.

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