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Real Rigidities and the Non-Neutrality of Money

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Rigidities in real prices are not sufficient to create rigidities in nominal prices and real effects of nominal shocks. And, by themselves, small frictions in nominal adjustment, such as costs of changing prices, create only small non-neutralities. But this paper shows that substantial nominal rigidity can arise from a *combination* of real rigidities and small nominal frictions. The paper shows the connection between real and nominal rigidity given the presence of nominal frictions both in general and for two specific sources of real rigidity, one arising from goods market imperfections and the other from labour market imperfections.

I. INTRODUCTION

According to Keynesian economics, nominal wages and prices are rigid, and so nominal disturbances have real effects. Researchers have presented a wide range of explanations for wage and price rigidities; examples include implicit contracts, customer markets, social customs, efficiency wages, inventory models, and theories of countercyclical mark-ups.[1] These explanations have a common weakness, however: they are theories of *real* rather than *nominal* rigidities. That is, they attempt to explain why real wages or prices are unresponsive to changes in economic activity. Real rigidity does not imply nominal rigidity: without an independent source of nominal stickiness, prices adjust fully to nominal shocks regardless of the extent of real rigidities.

The purpose of this paper is to show that real rigidities nonetheless have a crucial role in explaining nominal rigidities and the non-neutrality of nominal shocks. While real rigidities alone are not sufficient, nominal rigidities can be explained by a *combination* of real rigidities and small frictions in nominal adjustment.

Real rigidities are important because nominal frictions alone—like real rigidities alone—are not enough to cause a large amount of nominal rigidity. In practice, the costs of making nominal prices and wages more flexible—for example, by adjusting prices more frequently or adopting greater indexation—appear small. Mankiw (1985) and Akerlof and Yellen (1985) show that small costs of changing prices ("menu costs")—or equivalently small departures from full optimization ("near rationality")—can *in principle* produce large nominal rigidities. We show, however, that without real rigidities this result

1. For implicit contracts, see for example Azariadis (1975) and Baily (1974); for customer markets, Okun (1981); for social customs, Akerlof (1980) and Romer (1984); for efficiency wages, Solow (1979), Shapiro and Stiglitz (1984), and Bulow and Summers (1986); for inventories, Blinder (1982); and for countercyclical markups, Stiglitz (1984), Rotemberg and Saloner (1986), and Bils (1986, 1987).

holds only for implausible parameter values; for example, labour supply must be highly elastic. For plausible parameter values, small nominal frictions produce only small rigidities. Thus Mankiw's and Akerlof and Yellen's argument, by itself, is not successful in providing foundations for the Keynesian assumption of nominal rigidity.

This paper shows that the argument can be rescued by introducing real rigidities. The degree of nominal rigidity arising from a given menu cost (or a given departure from full rationality) is increasing in the degree of real rigidity. Substantial real rigidity implies a large amount of nominal rigidity even if the menu cost is small.

The intuition behind these results is the following. Rigidity of prices after a nominal shock is a Nash equilibrium if the gain to a firm from changing its nominal price, given that other nominal prices are unchanged, is less than the cost of changing prices. But a change in one firm's nominal price when other nominal prices are fixed is a change in the firm's real price. Further, if other prices do not change, then the nominal shock affects real aggregate demand. Thus nominal rigidity is an equilibrium if a firm's gain from adjusting its real price in response to the change in real aggregate demand is less than the cost of changing prices. If the firm desires only a small change in its real price—that is, if there is a large degree of real rigidity—then the gain from making the change is small. Since real rigidity reduces the gain from adjustment, it increases the range of nominal shocks for which non-adjustment is an equilibrium.[2]

The remainder of the paper consists of five sections. Since our point is not tied to any specific source of real rigidity, Section II studies a quite general model. In this model imperfectly competitive price setters face a small menu cost. We show that the degree of nominal rigidity is increasing in the degree of real rigidity under broad conditions.

Section III shows that nominal frictions alone are not sufficient for large non-neutralities. We present a specific example of the general model of Section II in which imperfect competition and the menu cost are the only departures from Walrasian assumptions. We show that for plausible parameter values the model implies only small nominal rigidities.

The following two sections illustrate the general relation between real and nominal rigidity. Each section adds a specific source of real rigidity to the model of Section III and shows that large non-neutralities can result. In Section IV, the real rigidity arises in the goods market. Specifically, we combine our basic model with a model of imperfect information and customer markets based on Stiglitz (1979, 1984) and Woglom (1982). Real price rigidity arises from an asymmetry in the demand curves facing firms. In Section V, the real rigidity arises in the labour market. Real wages are rigid because firms pay efficiency wages to deter shirking.

Section VI offers concluding remarks.

II. GENERAL RESULTS

A. *Assumptions and overview*

Consider an economy consisting of a large number of price-setting agents. We assume that agent i's utility depends on aggregate real spending in the economy, Y, and on the agent's relative price, P_i/P.[3] In addition, there is a small cost, z, of changing nominal

2. Blanchard (1987*a*, *b*) also argues that real rigidities increase the real effects of nominal disturbances.

3. Our general results do not depend on particular definitions of Y and the price level P (that is, they do not depend on how we aggregate over agents). Our only assumption is that if all agents (or, since the economy is large, all but one) choose the same price, then P equals this price.

prices—the menu cost. Thus agent i's utility is given by

$$U_i = W\left(Y, \frac{P_i}{P}\right) - zD_i, \tag{1}$$

where D_i is a dummy variable that indicates whether the agent changes his nominal price. In the specific models of later sections, an agent is usually a "yeoman farmer" who sells a differentiated good that he produces with his own labour. We also, however, consider the case in which farmers hire each other in a labour market. Finally, it is straightforward to extend our analysis to the case in which (1) is the profit function of an imperfectly competitive firm; the model is then closed by assuming that firms are owned by households. Under all these interpretations, Y affects an agent's utility (or profits) by shifting out the demand curve that he faces—greater aggregate demand implies that the agent's sales are higher at a given relative price. P_i/P affects utility by determining the point on the demand curve at which the agent produces.

To make nominal disturbances possible, we introduce money. Assume that a transactions technology determines the relation between aggregate spending and real money balances:

$$Y = \frac{M}{P}, \tag{2}$$

where M is the nominal money stock.[4] Substituting (2) into (1) yields

$$U_i = W\left(\frac{M}{P}, \frac{P_i}{P}\right) - zD_i. \tag{3}$$

We assume that in the absence of menu costs, there is a symmetric equilibrium in prices ($P_i/P = 1$, $\forall i$) for a unique level of M/P. We normalize this level to be one; in other words, we assume that $W_2(1, 1) = 0$ (subscripts denote partial derivatives). We also assume that $W_{22}(1, 1) < 0$ (price setters' second-order condition) and that $W_{12} > 0$ (which guarantees stability of the equilibrium).

Part B of this section derives the degree of real price rigidity. We measure real rigidity by the responsiveness of agents' desired real prices, neglecting the menu cost, to shifts in real economic activity. Part C derives the degree of nominal rigidity, defined by the largest monetary shock to which prices do not adjust. Under broad conditions, changes in $W(\cdot)$ that raise the degree of real rigidity lead to greater nominal rigidity as well. Finally, Part D computes the welfare loss from equilibrium nominal rigidity and shows that it also usually increases with real rigidity. Thus real rigidities bolster the Keynesian view that economic fluctuations resulting from nominal shocks are highly inefficient.

B. Real rigidity

Let P_i^*/P be agent i's utility-maximizing real price in the absence of menu costs. This price is defined by the first-order condition $W_2(M/P, P_i^*/P) = 0$. Differentiating this

4. The purpose of (2) is not to advance a particular theory of money but simply to introduce a downward-sloping aggregate demand curve—a negative relation between Y and P. Our results would not change if, following Blanchard and Kiyotaki (1987), we introduced money by adding real balances to utility. In addition, while we assume below that fluctuations in aggregate demand arise from fluctuations in money, it would be straightforward to introduce velocity shocks instead.

condition with respect to M/P yields

$$\frac{d(P_i^*/P)}{d(M/P)}=\frac{-W_{12}}{W_{22}}\equiv\pi, \tag{4}$$

where henceforth we evaluate all derivatives at (1, 1), the equilibrium in the absence of menu costs. We define a high degree of real rigidity as a small value of π—a small responsiveness of an agent's desired real price to changes in aggregate real spending.

Equation (4) shows that a high degree of real rigidity can result from a large value of $-W_{22}$ or a small value of W_{12}. Intuitively, when $-W_{22}$ is large—that is, when utility is very concave in an agent's relative price—changes in the price are very costly. When W_{12} is small, shifts in real money have little effect on W_2, which determines the desired price.

C. The equilibrium degree of nominal rigidity

We measure nominal rigidity through an experiment similar to ones in previous work on menu costs (Mankiw (1985); Blanchard and Kiyotaki (1987); Ball and Romer (1989)). Suppose that agents set prices believing that M will equal one (a normalization). Each agent sets his price to one, the frictionless equilibrium in this case. After prices are set, however, there is an unanticipated shock to M. At this point each agent has the option of paying the menu cost z and adjusting his price. We solve for the range of realizations of M for which non-adjustment of all prices is a Nash equilibrium. This range is symmetric around one; we therefore denote it by $(1-x^*, 1+x^*)$ and use x^* as our measure of nominal rigidity. We show that a broad class of changes in $W(\cdot)$ that raise real rigidity raise x^* as well.

To determine when non-adjustment is an equilibrium, we compare an agent's utility if he adjusts his price and if he does not, given that other agents do not adjust. If agent i maintains a rigid price of one along with the others, then $D_i=0$, $M/P=M$, and $P_i/P=1$. Thus the agent's utility is $W(M, 1)$. If the agent adjusts despite others' non-adjustment, then $D_i=1$ and the agent sets P_i/P to P_i^*/P, the utility-maximizing level given M/P. Since one agent's behaviour does not affect the aggregate price level, M/P is still simply M. Thus the agent's utility is $W(M, P_i^*/P)-z$.

These results imply that agent i does not adjust—and so rigidity is an equilibrium—if

$$PC<z, \qquad PC=W\left(M,\frac{P_i^*}{P}\right)-W(M,1). \tag{5}$$

PC is the "private cost" of nominal rigidity: an agent's loss from not setting his relative price at the utility-maximizing level. Rigidity is an equilibrium if this loss is less than the menu cost. A second-order Taylor approximation around $M=1$ yields

$$PC\simeq\frac{-(W_{12})^2}{2W_{22}}x^2, \tag{6}$$

where $x\equiv M-1$.[5] Equations (5) and (6) imply that rigidity is an equilibrium when M

5. A second-order approximation of $W(M,P_i^*/P)-W(M,1)$ yields

$$\left\{W(1,1)+\left[W_1+W_2\frac{\partial P_i^*/P}{\partial M}\right]x+\frac{1}{2}\left[W_{11}+2W_{12}\frac{\partial P_i^*/P}{\partial M}+W_{22}\left(\frac{\partial P_i^*/P}{\partial M}\right)^2+W_2\frac{\partial^2 P_i^*/P}{\partial M^2}\right]x^2\right\}$$
$$-\{W(1,1)+W_1x+\tfrac{1}{2}W_{11}x^2\}.$$

Using $W_2=0$ (agents initially set prices optimally given expected M) and $\partial(P_i^*/P)/\partial M=-W_{12}/W_{22}$ (from (4)), this expression simplifies to (6).

lies within $(1-x^*, 1+x^*)$, where

$$x^* = \sqrt{\frac{-2W_{22}z}{(W_{12})^2}}. \quad (7)$$

We can now show the connection between real and nominal rigidity. Using $\pi = -W_{12}/W_{22}$, we can rewrite (7) as

$$x^* = \sqrt{\frac{2z}{\pi W_{12}}}. \quad (8)$$

If there is no nominal friction, then nominal prices are completely flexible: $x^* \equiv 0$ if $z = 0$. But for a positive menu cost, increasing real rigidity—that is, decreasing π—by either decreasing W_{12} or increasing $-W_{22}$ leads to greater nominal rigidity. (A lower W_{12} raises x^* directly as well as through π.) As π approaches zero, the degree of nominal rigidity becomes arbitrarily large.[6]

To understand the connection between x^* and π, recall that nominal rigidity is an equilibrium if an agent does not adjust his nominal price to a nominal shock given that others do not adjust. As explained in the introduction, non-adjustment along with the others implies a constant real price, and the others' behaviour implies that the nominal shock affects real aggregate demand; thus nominal rigidity is an equilibrium if an agent does not adjust his real price when demand shifts. An increase in real rigidity means that an agent desires a smaller change in his real price after a given change in demand. When the desired change is smaller, the cost of foregoing it is smaller; thus a menu cost is sufficient to prevent adjustment for a wider range of shocks.

So far we have focused on the conditions under which nominal rigidity is an equilibrium. It is also natural to ask when *flexibility* is an equilibrium. Analysis parallel to the derivation of (7) shows that adjustment of all prices is an equilibrium if $|x| > x^{**}$, where

$$x^{**} = \sqrt{\frac{2z}{-W_{22}}}. \quad (9)$$

As discussed in Ball and Romer (1988), x^{**} can be less than x^*. In this case there is a range of shocks, $x^{**} < |x| < x^*$, for which both rigidity and flexibility are equilibria. Intuitively, multiple equilibria arise from "strategic complementarity" in price setting: an agent's desired price depends positively on others' prices, so adjustment by others raises his incentive to adjust.

Equations (9) and (7) imply that $x^*/x^{**} = 1/\pi$. Thus multiple equilibria require sufficient real rigidity ($\pi < 1$), and greater real rigidity increases the range of multiple equilibria. Real rigidity strengthens strategic complementarity in price setting—when agents want stable real prices, their desired nominal prices are closely tied to others' prices.

These results suggest a caveat to our main argument. According to (9), increasing real rigidity by raising $-W_{22}$ widens not only the range of shocks for which rigidity is an equilibrium, but also the range for which flexibility is an equilibrium. If we measure rigidity by x^{**} rather than x^*, real rigidity can lead to *less* nominal rigidity. This result does not, however, affect our conclusion that real rigidity is necessary for substantial

6. Because the degree of nominal rigidity depends on more than the degree of real rigidity, one can construct examples in which changing a parameter increases real rigidity but lowers x^*. Specifically, this can occur if the change raises W_{12} and also raises $-W_{22}$ by a greater amount. But this is not a natural case. As we show in the specific models of later sections, plausible sources of real rigidity simply raise $-W_{22}$ or lower W_{12}.

nominal rigidity. As we show below, without real rigidities the degree of nominal rigidity is small even using the generous measure x^*. That is, without real rigidities, *all* equilibria have little nominal rigidity. Introducing real rigidities means that x^* can be large, so considerable nominal rigidity can be an equilibrium. The result that x^{**} can fall means only that the amount of rigidity in other equilibria can go from small to smaller.[7]

D. The welfare loss from nominal rigidity

Since real rigidity increases nominal rigidity, it increases the economic fluctuations resulting from shocks to aggregate demand. Conventional Keynesian doctrine holds not only that such fluctuations are large, but also that they are highly undesirable. In an earlier paper (Ball and Romer (1989)) we analyse the welfare costs of fluctuations arising from nominal rigidity in a model with few departures from Walrasian assumptions. We find that the costs are small for plausible parameter values. Here, we show that real rigidities can alter this conclusion: greater real rigidity implies greater welfare costs of equilibrium nominal rigidity.

For our welfare analysis, we modify the experiment of the last section in two ways. First, as in our previous paper, we assume for simplicity that agents must decide whether to pay the menu cost *before* observing the money supply. If an agent pays, he can always adjust his price ex post; if he does not pay, his price is always rigid. This nominal rigidity is a zero-one variable. This simplification does not affect the qualitative results.

Second, to study the effects of fluctuations we posit a distribution for M rather than simply considering an unanticipated shock. Let the mean of M be one and let σ^2 denote its variance. In this case, the price, P_0, that agents set before observing M is not equal to the expected value of M: certainty equivalence fails because utility is not quadratic. Following our earlier paper, one can show that[8]

$$\frac{1}{P_0} \simeq 1 - \frac{W_{211}}{2W_{12}}\sigma^2. \tag{10}$$

Thus the mean level of output under rigidity, $E[M]/P_0$, differs from one, its level under flexibility.

In this version of the model, reasoning parallel to the derivation of (5)-(6) shows that (complete) rigidity is an equilibrium if

$$PC < z, \qquad PC \simeq \frac{-(W_{12})^2}{2W_{22}}\sigma^2. \tag{11}$$

Comparing (11) with (6) shows that $\sigma^2 = E[(M-1)^2]$ replaces $x^2 = (M-1)^2$. In choosing between rigidity and flexibility ex ante, agents compare the menu cost to the *expected* private loss from rigidity.

The welfare loss from equilibrium rigidity depends on the relation between PC and the "social cost" or rigidity: the difference between $E[W(\cdot)]$ when all agents pay the menu cost and when none pays. If all agents pay, then $M/P = 1$ and $P_i/P = 1$ (the

7. When both rigidity and flexibility are equilibria, perhaps the more "natural" equilibrium is rigidity—doing nothing. This idea can be formalized by allowing agents to delay adjustment until they see what others do.

8. The first-order condition for agent i's price under rigidity, P_{0i}, is $E[W_2(M/P_0, P_{0i}/P_0)] = 0$. Equilibrium requires $P_{0i} = P_0$. Thus the equilibrium P_0 is defined by $E[W_2(M/P_0, 1)] = 0$. Expanding this condition around $M = 1$ gives (10).

equilibrium under flexible prices); thus $E[W(\cdot)] = W(1,1)$. If no agent pays, then all nominal prices equal P_0 and $E[W(\cdot)] = E[W(M/P_0,1)]$. Thus the social cost is

$$SC = W(1,1) - E[W(M/P_0,1)]$$
$$\simeq \frac{W_1 W_{211} - W_{11} W_{12}}{2W_{12}} \sigma^2, \tag{12}$$

where we again approximate around $M = 1$.

Combining (11) and (12) yields the ratio of the social to the private cost of rigidity:

$$R = \frac{SC}{PC} = \frac{W_{22}(W_{11} W_{12} - W_1 W_{211})}{(W_{12})^3}. \tag{13}$$

Recall that nominal rigidity is an equilibrium as long as the private cost does not exceed z. The largest possible social cost of equilibrium rigidity is thus R times z. Since the losses from rigidity disappear when $\sigma^2 = 0$, Rz is also the maximum gain from stabilizing aggregate demand. Thus, for a given menu cost z, the welfare cost of rigidity and the gains from demand stabilization are increasing in R. As discussed in Ball and Romer (1989), R can be greater than one—the social cost of nominal rigidity can exceed the private cost—because rigidity has a negative externality. Rigidity in one agent's price contributes to rigidity in the aggregate price level. Greater price level rigidity causes larger fluctuations in real spending, which harms all agents.

The size of R, like the degree of nominal rigidity, is linked to the degree of real rigidity. Consider first an increase in real rigidity caused by an increase in $-W_{22}$. As described above, this reduces the private cost of nominal rigidity—the gain from adjusting to a shock if others do not adjust. In contrast, the social cost of nominal rigidity is unaffected. Intuitively, real rigidity is irrelevant to the difference in welfare when all prices adjust and when none adjusts because all real prices are one in both cases. Thus real rigidity increases the ratio of social to private costs of nominal rigidity by reducing the denominator while leaving the numerator unchanged.

The effect of an increase in real rigidity caused by a decrease in W_{12} is more complicated. A lower W_{12}, like a higher $-W_{22}$, reduces the private cost of rigidity. But in principle W_{12} affects the social cost as well, because it affects P_0 and hence the mean level of output under rigidity. As a result, reducing W_{12} has in general an ambiguous effect on R. In the specific models of Sections IV and V, however, the effect of rigidity on mean output proves to be unimportant. Ignoring this effect, a smaller W_{12} has the same implications as a larger $-W_{22}$: R rises because its denominator falls and its numerator is unchanged.

III. A BASELINE MODEL

This section considers a simple example of the class of models studied above. Aside from imperfect competition and the menu cost, the model's assumptions are Walrasian. We use the model to show that menu costs are not enough to produce large real effects of money; specifically, we show that the degree of nominal rigidity and the welfare loss from rigidity are small for plausible parameter values. The model is also the basis for Sections IV and V. In those sections, we add specific sources of real rigidity and show that large non-neutralities can result.

A. The model

We consider a simple "yeoman farmer" economy similar to those in Ball and Romer (1988, 1989). There is a continuum of agents ("farmers") indexed by i and distributed uniformly on [0, 1]. Each farmer uses his own labour to produce a differentiated good, then sells this product and purchases the products of all other farmers. Farmer i's utility function is

$$U_i = C_i - \frac{\varepsilon - 1}{\gamma\varepsilon} L_i^{\gamma} - zD_i, \qquad C_i = \left[\int_{j=0}^{1} C_{ij}^{(\varepsilon-1)/\varepsilon} dj\right]^{\varepsilon/(\varepsilon-1)}, \tag{14}$$

where L_i is farmer i's labour supply, C_i is an index of farmer i's consumption, C_{ij} is farmer i's consumption of the product of farmer j, ε is the elasticity of substitution between any two goods ($\varepsilon > 1$), and γ measures the extent of increasing marginal disutility of labour ($\gamma > 1$). The coefficient on L_i is chosen so that equilibrium output neglecting menu costs is one.

Farmer i has a linear production function:

$$Y_i = L_i, \tag{15}$$

where Y_i is the farmer's output. As in Section II, a transactions technology implies

$$Y = \frac{M}{P}, \tag{16}$$

where in this model

$$Y = \int_{i=0}^{1} Y_i di; \qquad P = \left[\int_{i=0}^{1} P_i^{1-\varepsilon} di\right]^{1/(1-\varepsilon)}. \tag{17}$$

P is the price index for consumption, C_i.

Equations (14)-(17) determine the demand for farmer i's product:

$$Y_i^D = \left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{-\varepsilon}. \tag{18}$$

Substituting (18) and the farmer's budget constraint ($PC_i = P_i Y_i$) into (14) yields the specific form of $W(\cdot)$ in this model:

$$\begin{aligned} U_i &= \left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{(1-\varepsilon)} - \frac{\varepsilon-1}{\gamma\varepsilon}\left(\frac{M}{P}\right)^{\gamma}\left(\frac{P_i}{P}\right)^{-\gamma\varepsilon} - zD_i \\ &\equiv W\left(\frac{M}{P}, \frac{P_i}{P}\right). \end{aligned} \tag{19}$$

B. Are the non-neutralities large?

We can now determine the degree of nominal rigidity and the welfare loss from rigidity in this model. Taking the appropriate derivatives of (19), evaluating at (1,1), and substituting into (7) and (13) yields

$$x^* = \sqrt{\frac{2(1+\gamma\varepsilon-\varepsilon)z}{(\varepsilon-1)(\gamma-1)^2}}; \qquad R = \frac{(1+\varepsilon\gamma-\varepsilon)^2}{\varepsilon(\varepsilon-1)(\gamma-1)^2}. \tag{20}$$

As in previous papers, a second-order menu cost leads to first-order nominal rigidity (x^* is proportional to $\sqrt{z}$). But this does not imply that menu costs prevent adjustment to sizable shocks. Similarly, R is greater than one, but this does not imply that menu costs cause large welfare losses; since the loss from equilibrium rigidity is Rz and z is small, R must be much greater than one. We now show that in this model x^* and R are small for plausible parameter values. The results for R are more clear-cut than the results for x^*.

Table 1 shows the private cost of non-adjustment to a 5% change in the money supply, measured as a percentage of a farmer's revenue when all prices are flexible, for various values of ε and γ.[9] The private cost equals the menu cost needed to prevent adjustments to the shock—that is, to make x^* greater than 0.05. The table also shows the values of R corresponding to the values of ε and γ. To interpret the results, note that non-adjustment to a 5% change in money implies a 5% change in real output. Recall that ε is the elasticity of demand for a farmer's product and γ measures the degree of increasing marginal disutility of labour. The table presents the private cost and R as functions of $1/(\varepsilon-1)$, the markup of price over marginal cost, and $1/(\gamma-1)$, farmer's labour supply elasticity.

TABLE 1

Baseline Model

Labour supply elasticity ($1/(\gamma-1)$)	Private cost/R Markup ($1/(\varepsilon-1)$) 5%	 15%	 50%	 100%
0·05	2·38/1·05	2·16/1·16	1·64/1·55	1·22/2·10
0·15	0·79/1·06	0·71/1·19	0·53/1·65	0·39/2·31
0·50	0·23/1·10	0·20/1·30	0·14/2·04	0·10/3·13
1·00	0·11/1·15	0·10/1·47	0·06/2·67	0·04/4·50

Note. Private cost is for a 5% change in money, and is measured as a percentage of revenue when prices are flexible.

We focus on a base case in which, using evidence from empirical studies, we take 0.15 as the value of the markup and 0.15 again as the labour supply elasticity; these numbers imply $\varepsilon=\gamma=7{\cdot}7$.[10] For these values, the private cost of rigidity is 0·7% of revenue, which appears non-negligible. Thus, while it is difficult to determine "realistic" values for costs of adjusting nominal prices, trivial costs would not be sufficient to prevent adjustment in this example. In any case, the welfare result is very clear. When both the markup and the labour supply elasticity are 0·15, R is 1·2—the social cost of rigidity is only slightly greater than the private cost. Since the welfare loss from rigidity is bounded by Rz, $R=1{\cdot}2$ and small menu costs imply that this loss is small.

Table 1 shows that it is difficult to reverse these results. The private cost of rigidity is decreasing in both the markup and the labour supply elasticity, and approaches zero as either approaches infinity. But implausibly large values of these parameters are required for large non-neutralities. To see this, consider a labour supply elasticity of one (well above most estimates) and a markup of one (generous even compared with the high estimates in Hall (1988)). In this case, the private cost of non-adjustment to a 5% change

9. Blanchard and Kiyotaki (1987) present similar calculations. While the private cost is measured in units of utility and revenue is measured in dollars, it is legitimate to compare them because the marginal utility of income is one.

10. For evidence on markups, see Scherer (1980); for labour supply elasticities, see Killingsworth (1983).

in money is 0·04% of revenue, which is perhaps trivial. But $R = 4{\cdot}5$: the welfare cost of the business cycle is only 4·5 times the menu cost. Only outlandish parameter values yield a large R—for example, a markup of one and labour supply elasticity of 10 imply $R = 72$.

Intuitively, the crucial problem for the model is that labour supply appears to be unelastic (that is, realistic values of γ are large). Since workers are reluctant to vary their hours of work, they have a strong incentive to adjust their wages (equal to their product prices in our yeoman farmer model) when demand changes. Large private gains from flexibility imply that farmers pay the menu cost after a nominal shock unless the shock is very small, and thus that only small shocks affect output and welfare.

These results are strengthened by a natural modification of the model. In studying a yeoman farmer economy, we implicitly introduce an additional imperfection besides the menu cost and imperfect competition: immobile labour. If farmers sell labour to each other in a competitive market (a case considered in Section V), the private cost of price rigidity is greatly increased. If, for example, the money stock falls and prices do not adjust, then output falls and the lower labour demand reduces the real wage. Since a producer can hire as much labour as he wants at the low wage, he can greatly increase profits by cutting his price and raising output. With self-employment, the gains from increasing output are smaller because the producer faces his own upward-sloping labour supply curve. If labour supply is inelastic, this difference in incentives to adjust is very large. For a markup and labour supply elasticity of 0·15, introducing labour mobility raises the private cost in Table 1 from 0·7% of revenue to 38%. With such strong incentives to adjust, nominal frictions produce *extremely* small non-neutralities.

IV. IMPERFECT INFORMATION AND CUSTOMER MARKETS

A. *Overview*

This section and the next present examples in which we add sources of real rigidity to the model of Section III and show that large non-neutralities can result. Here, the source of rigidity is an asymmetry in the effects on demand of price increases and decreases that has been explored by Stiglitz (1979, 1984) and Woglom (1982). The central assumption is that changes in a firm's price are observed by the firm's current customers but not by other consumers. If the firm raises its price, it loses sales both because some of its customers leave for other sellers and because its remaining customers buy less. If the firm lowers its price, it sells more to current customers, but it does *not* attract other firms' customers, because they do not observe the lower price.[11]

To introduce this asymmetry in demand, we modify our basic model by assuming that each good is produced by many farmers rather than by one, and that each farmer sells to a group of customers rather than to everyone. In addition, we introduce heterogeneity in tastes that causes the proportion of a farmer's customers who leave to be a smooth function of the farmer's price. Thus, while Stiglitz and Woglom study demand curves with kinks, we focus on the more appealing case of demand curves that bend sharply but are nonetheless differentiable at all points. (Kinked demand curves are a limiting case of our model; we discuss the special features of this case below.)

11. We choose this source of real rigidity because we are able to formalize it rigorously. If one is willing to introduce an *ad hoc* rigidity, our results can be illustrated more simply. Our working paper (Ball and Romer (1987)) presents an example in which we simply add a quadratic cost of adjusting real prices to agents' objective functions. The resulting increase in real rigidity implies greater nominal rigidity as well.

Part B of this section presents the revised model. Part C derives the demand curve facing a farmer and shows that it is asymmetric. Part D shows that the asymmetry in demand leads to real price rigidity. Part E demonstrates the link between real and nominal rigidity in this example. Finally, Part F asks how much real rigidity is needed to generate nominal rigidity that is quantitatively important.

B. Assumptions

There is a continuum of differentiated goods, each produced by a continuum of farmers. Goods are indexed by j and distributed uniformly on the unit interval; farmers are indexed by j and k and distributed uniformly on the unit square. We let $i=(j, k)$ denote a point in the unit square.

Each farmer consumes all products but purchases a given product from only one farmer, his "home seller" of that good. A farmer observes the prices of his home sellers. He does not observe other individual prices, but he knows the distribution of prices for each good. In his role as a seller, each farmer is the home seller to a continuum of farmers, his customers. Each producer of good j begins as the home seller of an equal proportion of all farmers.

As in our other models, each seller sets a nominal price before observing the money stock and adjusts after M is revealed if he pays the menu cost. After prices are determined, each farmer chooses whether to leave each of his home sellers for another seller of the same product. For simplicity, we assume that this search is costless, but that a farmer can search for a seller of a given product only once: if the farmer leaves his home seller, he is assigned to another and can neither search again nor return to his original home seller. (Our results would not change if we introduced a search cost and allowed farmers to choose how many times to search.) If a farmer leaves his home seller of a given product, he has an equal chance of being assigned to each other seller of the product.

We introduce heterogeneity in tastes by modifying the utility function, (14), to be

$$U_i = AC_i - BL_i^{\gamma} - zD_i, \tag{21}$$

where

$$C_i = \left\{ \int_{j=0}^{1} [(\theta_{ij})^{D(ij)} C_{ij}]^{(\varepsilon-1)/\varepsilon} dj \right\}^{\varepsilon/(\varepsilon-1)}. \tag{22}$$

$D(ij)$ is a dummy variable equal to one if farmer i remains with his home seller of product j; θ_{ij} measures farmer i's taste for remaining with his home seller of product j; and A and B are constants chosen for convenience.[12] The important change in the utility function is the addition of the θ_{ij}'s to the consumption index. In words, farmer i's utility gain from one unit of product j provided by his home seller equals his gain from θ_{ij} units from a different seller. We can interpret farmers' tastes for their home sellers as arising from location, service, and the like. For simplicity, a farmer is indifferent among all sellers of a given product who are not his home seller.

We assume that θ_{ij} is distributed across i with a cumulative distribution function, $F(\cdot)$, which is the same for all j. We also assume that the mean of θ_{ij}, $\bar{\theta}$, is greater than

12. The definitions of A and B are:

$$A = \left[F(1) + \int_{\theta=1}^{\infty} \theta^{\varepsilon-1} f(\theta) d\theta \right]^{1/(1-\varepsilon)}; \qquad B = \frac{(\varepsilon-1)A^{1-\varepsilon} + f(1)}{[\varepsilon A^{1-\varepsilon} + f(1)]\gamma},$$

where $F(\cdot)$ and $f(\cdot)$ are defined below.

one and that the density function of θ_{ij}, $f(\cdot)$, is symmetric around $\bar{\theta}$ and single-peaked. The assumption that $\bar{\theta}$ is greater than one means that, all else equal, most buyers prefer to remain with their home sellers. This (plausible) assumption is necessary for imperfect information to lead to asymmetric demand. If θ had mean one, then half of a farmer's customers would leave if he charged a real price of one, and this would imply that price decreases save as many customers as price increases drive away.

Aside from the modifications described here, the model is the same as in Section III.

C. *Product demand*

The first step in studying this model is to derive the demand curve facing a seller. We consider the case in which all other sellers charge a real price of one; the analysis below requires only the results for this case. Farmer i sells to two groups of customers: original customers who remain with him after they observe his price, and customers of other sellers who leave and are assigned to him. An original customer stays if this maximizes his utility gain per unit of expenditure; when others' real prices are one, this occurs for $P_i/P < \theta$.[13] One can show that if a customer stays, his demand for the farmer's product is

$$(A\theta)^{(\varepsilon-1)}\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right). \tag{23}$$

The fraction of other farmers' customers who leave is $F(1)$, the fraction with θ less than the others' real price of one. By our symmetry assumptions, the new customers assigned to farmer i are proportion $F(1)$ of his original customers. Finally, the demand from each new customer is given by (23) with θ replaced by one, since $\theta^{D(ij)} \equiv 1$ for buyers who switch sellers. Combining these results leads to total demand for farmer i's product:

$$\begin{aligned} Y_i^D &= A^{\varepsilon-1}\left\{F(1)+\int_{\theta=P_i/P}^{\infty}\theta^{\varepsilon-1}f(\theta)\,d\theta\right\}\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right) \\ &\equiv A^{\varepsilon-1}h\left(\frac{P_i}{P}\right)\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right). \end{aligned} \tag{24}$$

Intuitively, $h(P_i/P)$ gives the effect of farmer i's price on his number of customers, and (as usual) $(P_i/P)^{-\varepsilon}$ determines how much each customer buys.

Equation (24) implies asymmetric responses to increases and decreases in a farmer's price. Straightforward computations lead to

$$\begin{aligned} \eta &\equiv -\left.\frac{\partial \ln Y_i^D}{\partial \ln (P_i/P)}\right|_{(P_i/P)=1} = \varepsilon+\frac{f(1)}{h(1)}; \\ \rho &\equiv -\left.\frac{\partial^2 \ln Y_i^D}{\partial \ln (P_i/P)^2}\right|_{(P_i/P)=1} = \eta\frac{f(1)}{h(1)}+\frac{f'(1)}{h(1)}. \end{aligned} \tag{25}$$

η is the elasticity of demand evaluated at one, the farmer's ex ante real price, and ρ measures the change in the elasticity as the farmer's price rises around one. $\rho > 0$ implies that price increases have larger effects on demand than price decreases. A sufficient condition for $\rho > 0$ is $f'(1) > 0$, which is guaranteed by our assumptions that $E[\theta] > 1$ and that $f(\cdot)$ is increasing below its mean. If $f'(1)$ is large, then the asymmetry in demand is strong—the demand curve bends sharply around one.

13. More precisely, if farmer i sells product j to farmer i', then farmer i' remains if $P_i/P < \theta_{i'j}$. In the text, we suppress subscripts for simplicity.

As in Stiglitz and Woglom, imperfect information is the source of asymmetric demand. A price increase drives away customers, but a decrease does not attract new customers, because customers of other sellers do not observe it. The details of the results are more complicated than in previous papers, however. Stiglitz and Woglom assume that a firm retains all its customers if it charges a real price of one, but we assume that the firm loses some customers (those with $\theta < 1$). Thus in our model a price decrease *does* raise the number of customers: it saves some old customers who otherwise would leave. Demand is still asymmetric, because our assumptions about $F(\cdot)$ imply that the number saved is less than the number lost by an increase.

Figure 1 illustrates the asymmetry in our model. Since farmer i retains original customers for whom $\theta > P_i/P$, the proportion of customers who stay is given by the area under $f(\cdot)$ to the right of P_i/P. The change in this proportion resulting from a price change is the area under $f(\cdot)$ between the old and new prices. Figure 1 shows that a price increase starting from $P_i/P = 1$ has a larger effect on the proportion who stay than a price decrease, because $f'(1) > 1$.

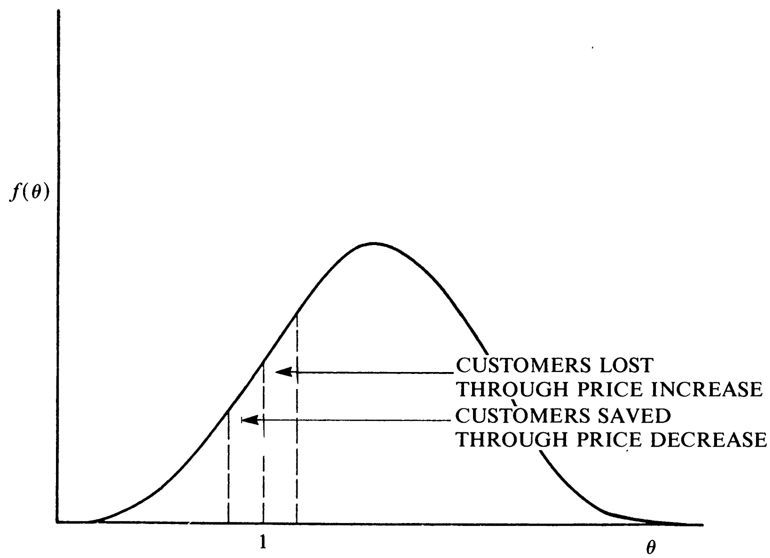

FIGURE 1
Imperfect information model: asymmetric effects of price changes

There are two limiting cases of our model. The first is $f(1) = f'(1) = 0$, which implies that all customers remain with a farmer if his price is in the neighbourhood of one. In this case, $\eta = \varepsilon$, $\rho = 0$, and the demand function reduces to (18), the symmetric function in the basic model. The second case is $f(\theta) = 0$ for $\theta < 1$ and $f'(1) \to \infty$. This implies $\rho \to \infty$: the demand curve is kinked, as in Stiglitz and Woglom. In this case, all customers remain as long as $P_i/P \leqq 1$, but a non-negligible proportion leaves as soon as the price rises above one.

D. Real rigidity

Substituting the demand equation, (24), into the utility function, (21), yields $W(\cdot)$ for this model:

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

$$\equiv W\left(\frac{M}{P},\frac{P_i}{P}\right) - zD_i. \tag{26}$$

Substituting the appropriate derivatives of $W(\cdot)$ into the definition of π yields

$$\pi = \frac{\eta(\gamma-1)(\eta-1)}{\eta(\eta-1)(1+\gamma\eta-\eta)+\rho}; \qquad \frac{\partial\pi}{\partial\rho}<0; \qquad \lim_{\rho\to\infty}\pi = 0. \tag{27}$$

According to (27), real prices become more rigid as demand becomes more asymmetric. As the bend in the demand curve approaches a kink ($\rho \to \infty$), real prices become completely rigid. Intuitively, a sharply bent demand curve means that price increases greatly reduce demand but decreases raise demand only a little. In this case, both increases and decreases are unattractive and farmers maintain rigid prices.

E. Nominal rigidity

We can now show the connection between real and nominal rigidity in this model. Substituting the derivatives of (26) into (7) and (13) yields

$$x^* = \sqrt{\frac{2[(\eta-1)(1+\gamma\eta-\eta)+(\rho/\eta)]z}{(\gamma-1)^2(\eta-1)^2}}; \tag{28}$$

$$R = \frac{(1+\gamma\eta-\eta)^2}{\eta(\eta-1)(\gamma-1)^2} + \frac{\rho}{\eta^2(\eta-1)(\gamma-1)}. \tag{29}$$

Both x^* and R are increasing in ρ, and both approach infinity as ρ approaches infinity. Thus increasing real rigidity by bending the demand curve leads to greater nominal rigidity, and complete real rigidity arising from kinked demand implies complete nominal rigidity. In terms of our general model, increases in ρ raise x^* and R because they increase $-W_{22}$ while leaving W_{12} unchanged—the bend in the demand curve makes a seller's utility more concave in his price.[14]

F. How much real rigidity is necessary?

In the baseline model of Section III, plausible parameter values imply that there is little nominal rigidity. We now ask how much real rigidity is needed to reverse this result. Table 2 presents the private cost of nominal rigidity (again assuming a 5% change in money) and R for various values of the markup, the labour supply elasticity, and the degree of real rigidity π. The markup is now $1/(\eta-1)$. Given the markup and labour

14. Stiglitz and Woglom argue that kinked demand can lead to nominal rigidity without referring explicitly to nominal frictions, which suggests that real rigidities alone can cause nominal rigidity. Nominal frictions are implicit in the Stiglitz-Woglom argument, however. Neglecting menu costs, kinked demand curves imply multiple real equilibria—for example, each firm will raise its price a small amount if all others do (this leaves relative prices unchanged but reduces real money). Crucially, nominal disturbances do not affect the set of real equilibria. Stiglitz and Woglom argue informally that nominal disturbances may move the economy from one real equilibrium to another—for example, if nominal money falls and prices do not adjust, which is one equilibrium response, then real money falls. This argument depends, however, on the idea that when there are several equilibrium responses to a shock, the one with fixed nominal prices, rather than the one with fixed real prices, is "natural". In turn, this depends on a notion of the convenience of fixing prices in nominal terms, which amounts to a small cost of nominal flexibility.

TABLE 2

Customer markets model

Private cost/R for various degrees of real rigidity			
$1/(\eta-1)=0{\cdot}15,\ 1/(\gamma-1)=0{\cdot}15$		$1/(\eta-1)=0{\cdot}15,\ 1/(\gamma-1)=1{\cdot}00$	
π	PC/R	π	PC/R
0·127*	0·71/1·19	0·115*	0·10/1·47
0·050	0·28/3·04	0·050	0·04/3·37
0·025	0·14/6·09	0·025	0·02/6·75
0·010	0·06/15·2	0·010	0·01/16·9
0·005	0·03/30·4	0·005	0·00/33·7
0·002	0·01/76·1	0·002	0·00/84·3
0·001	0·01/152·1	0·001	0·00/168·6
$1/(\eta-1)=1{\cdot}00,\ 1/(\gamma-1)=0{\cdot}15$		$1/(\eta-1)=1{\cdot}00,\ 1/(\gamma-1)=1{\cdot}00$	
π	PC/R	π	PC/R
0·474*	0·39/2·31	0·333*	0·04/4·50
0·200	0·17/5·37	0·200	0·03/7·50
0·050	0·04/21·5	0·050	0·01/30·0
0·025	0·02/43·0	0·025	0·00/60·0
0·010	0·01/107·5	0·010	0·00/150·0
0·005	0·00/214·9	0·005	0·00/300·0
0·002	0·00/537·3	0·002	0·00/750·0

* Real rigidity when $\rho=0$

Note. Private cost is for a 5% change in revenue, and is measured as a percentage of revenue when prices are flexible.

supply elasticity, there is a one-to-one relation between π and ρ; we present results in terms of π because ρ is difficult to interpret. Since the results about R are the most disappointing in Section III, we focus the present discussion on R.

Table 2 shows that a large degree of real rigidity is necessary for a large R. As a benchmark, note first that if $\rho=0$—there is no asymmetry in demand, so the model reduces to the one in Section III—a markup of 0·15 and a labour supply elasticity of 0·15 imply $\pi=0{\cdot}127$ and (as shown above) $R=1{\cdot}2$. Increasing ρ so that π falls to 0·05—that is, reducing the responses of real prices to demand shifts by more than half—raises R to 3·0, but this is still small. ($\pi=0{\cdot}05$ combined with a markup and labour supply elasticity of one implies $R=30$.) Larger reductions in π produce better results: $\pi=0{\cdot}01$ implies $R=15$ for a markup and labour supply elasticity of 0·15 (and $R=150$ for a markup and elasticity of one), and $\pi=0{\cdot}001$ implies $R=152$ (and 1500).

While these results show that the necessary amount of real rigidity is large, they do not determine whether this much rigidity is realistic. It is plausible that customer market considerations are quantitatively important—certainly there is no presumption that they are trivial, as with the costs of adjusting nominal prices. Research has not progressed far enough, however, to produce estimates of ρ, the sharpness of the bend in demand, or of the resulting real rigidity. Thus the question of whether customer markets are an important source of nominal rigidity remains open.

V. THE LABOUR MARKET AND REAL WAGE RIGIDITY

A. Discussion

Section IV suppresses the labour market and studies the implications of real price rigidity arising from product market imperfections. Traditionally, however, macroeconomists have viewed labour market imperfections as central to aggregate fluctuations. Motivated by this view, we now present a model with a labour market in which rigidity in firms' real prices is caused by rigidity in their real wages. Real wage rigidity arises because firms pay efficiency wages to elicit effort.[15,16]

The results of previous sections provide two more specific motivations for this section. First, the small degree of nominal rigidity in our basic yeoman farmer model arises largely from inelastic labour supply, which gives farmers strong incentives to stabilize their employment by adjusting prices. The analogue when firms hire workers in a Walrasian labour market is that inelastic labour supply implies highly procyclical real wages—large wage increases are needed to bring forth more labour supply. Highly procyclical real wages imply highly procyclical marginal costs, which in turn imply strong incentives for price adjustment when demand changes. A potential advantage of efficiency wage models is that firms set wages above the market clearing level. Since real wages are not tied directly to labour supply, inelastic labour supply need not imply procyclical real wages.

A second motivation for this section is the difficulty in Section IV of determining how much real price rigidity is realistic. This difficulty reflects uncertainty about the key parameter, the sharpness of the demand asymmetry. In this section, the degree of real price rigidity is determined by the degree of real wage rigidity—the responsiveness of real wages to demand shifts. We know something about this parameter; in particular, the acyclicality of real wages in actual economies suggests that a high degree of rigidity is realistic.

The analysis in this section is tentative because economists are not yet certain of the cyclical behaviour of efficiency wages. If firms pay efficiency wages to deter "shirking", real wages are procyclical (Shapiro and Stiglitz (1984)): when unemployment is high, workers fear the consequences of losing their jobs, and so firms can reduce wages without inducing shirking. It appears, however, that wages are less procyclical than in a competitive labour market. The degree of procyclicality depends on how steeply the cost of job loss rises with unemployment. If unemployed workers enter a secondary labour market (Bulow and Summers (1986)), this steepness depends on the extent of decreasing returns in the secondary sector, which may not be large. If unemployed workers simply search for new jobs, as in Shapiro–Stiglitz, the effect of unemployment on the cost of job loss depends on several parameters, including the rate at which exogenous separations create job openings. In this setting, unemployment has a smaller effect on efficiency wages than on competitive wages (Blanchard (1987*b*)).

While efficiency wage considerations appear to reduce the cyclicality of real wages, current models are too stylized to produce meaningful quantitative estimates of this effect. In the analysis below, we therefore calibrate the model using aggregate evidence that real wages are quite acyclical. It is not yet clear whether this aggregate behaviour can be generated by efficiency wage models with realistic microeconomic parameters. We simply show that *if* efficiency wages are highly acyclical, then they help to explain nominal rigidities.

15. Nominal rigidity still arises in prices but not wages because we do not introduce nominal frictions in wage setting. If we added such frictions, real wage rigidity would increase nominal wage rigidity just as real price rigidity increases nominal price rigidity.

16. Akerlof and Yellen (1985) also add efficiency wages to a model with a small nominal friction ("near-rationality"). They do not, however, investigate the link between real and nominal rigidity or the importance of efficiency wages for their quantitative results; they imply that imperfect competition and near-rationality alone are sufficient for large nominal rigidities. Akerlof and Yellen introduce efficiency wages so that nominal shocks affect involuntary unemployment as well as employment and output, and so that the costs to firms of nominal *wage* rigidity are not first order in the size of shocks.

B. A model

Since efficiency wages are a labour market phenomenon, a preliminary step is to modify our basic model by assuming that farmers work for each other rather than for themselves. Farmers have two sources of income, profits from their own farms and wages from working for others. Using the production function, (15), and the product demand equation, (18), one can derive the following expression for a farmer's utility:

$$U_i = wL_i + \left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{(1-\varepsilon)} - w\left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{-\varepsilon} - \frac{\varepsilon-1}{\gamma\varepsilon} L_i^{\gamma} - zD_i, \tag{30}$$

where w is the real wage. The first term in (30) is the farmer's labour income; the second (as in the basic model) the revenue from his farm; the third the wage bill he pays; and the fourth the disutility from the labour he supplies.

To see the importance of efficiency wages, first suppose that the labour market is Walrasian. Deriving a labour supply function from (30) and combining it with the production function and our assumption that $Y = M/P$, we obtain

$$w = \frac{\varepsilon-1}{\varepsilon}\left(\frac{M}{P}\right)^{\gamma-1}. \tag{31}$$

Equation (31) describes the cyclical behaviour of real wages with a Walrasian labour market. Note that inelastic labour supply (a large γ) implies highly procyclical wages. Equations (30) and (31) lead to the form of $W(\cdot)$ for this case:

$$W_{\text{Wal}}\left(\frac{M}{P}, \frac{P_i}{P}\right) = \frac{\varepsilon-1}{\varepsilon}\left(\frac{M}{P}\right)^{\gamma}\left[1-\left(\frac{P_i}{P}\right)^{-\varepsilon}\right] + \frac{M}{P}\left(\frac{P_i}{P}\right)^{1-\varepsilon} - \frac{\varepsilon-1}{\gamma\varepsilon}\left(\frac{M}{P}\right)^{\gamma}. \tag{32}$$

Now suppose that, as in Shapiro–Stiglitz, firms pay efficiency wages to deter shirking. That is, with imperfect monitoring of workers, firms pay wages above the market-clearing level to make it costly for workers to lose their jobs, thereby inducing effort. Effort is a zero-one variable, so firms pay the lowest wage that induces effort. As described above, a fall in aggregate employment raises the cost of job loss, and thus reduces the necessasry wage. Choosing a convenient functional form, we assume that the "no-shirking" wage is

$$\begin{aligned} w &= b\left(\frac{\varepsilon-1}{\varepsilon}\right)L^{\phi-1}, \qquad b>1, \quad \phi>1 \\ &= b\left(\frac{\varepsilon-1}{\varepsilon}\right)\left(\frac{M}{P}\right)^{\phi-1}. \end{aligned} \tag{33}$$

$b>1$ implies that in the vicinity of the no-shock equilibrium, wages are set above the market-clearing level, and so suppliers of labour are rationed. (Below we assume that b is close to one, so that the equilibrium unemployment rate is low.) Since workers are off their labour supply curves, the behaviour of the wage no longer depends on γ. As long as $\phi < \gamma$, real wages are less procyclical—that is, more rigid in the face of fluctuations in demand—than in a Walrasian market.

Following other efficiency wage models, we assume that part of the rationing of hours of work occurs through unemployment. Specifically, the division of labour input into workers and hours is given by

$$E_i = (L_i^D)^a; \tag{34}$$

$$H_i = (L_i^D)^{1-a}, \qquad 0<a<1, \tag{35}$$

where E_i is the number of workers hired by farmer i, H_i is hours per worker, and $L_i^D = E_iH_i$ is the amount of labour the farmer hires. We assume that workers are divided between employment and unemployment randomly. (The division of L_i^D into E_i and H_i proves irrelevant to the degree of nominal rigidity, x^*, but relevant to the welfare loss from rigidity.)

In this model, $W(\cdot)$ is a farmer's expected utility given his probability of employment. Since the size of the labour force is one, this probability is equal to E_i (equation (34)). The farmer's utility is determined by (30) with the wage given by (33) and the farmer's labour supply equal to H_i (equation (35)) when employed and zero when unemployed. Combining these results and using the fact that $L_i^D = Y_i = M/P$ yields

$$W_{\text{EW}}\left(\frac{M}{P}, \frac{P_i}{P}\right) = b\frac{\varepsilon-1}{\varepsilon}\left(\frac{M}{P}\right)^{\phi}\left[1-\left(\frac{P_i}{P}\right)^{-\varepsilon}\right] + \frac{M}{P}\left(\frac{P_i}{P}\right)^{1-\varepsilon} - \frac{\varepsilon-1}{\gamma\varepsilon}\left(\frac{M}{P}\right)^{(1-a)\gamma+a}. \quad (36)$$

C. *Real and nominal rigidity*

The solutions for $W(\cdot)$ in the two models lead to simple expressions for the degree of real price rigidity:

$$\pi_{\text{Wal}} = \gamma - 1; \qquad \pi_{\text{EW}} = \phi - 1. \quad (37)$$

If real wages are more rigid under efficiency wages ($\phi < \gamma$), real prices are also more rigid. In terms of our general model, efficiency wages increase real price rigidity by lowering W_{12} while leaving W_{22} unchanged. In this respect the current model differs from the one in Section IV, where real rigidity arises from a higher $-W_{22}$.

To see the implications of efficiency wages for nominal rigidity, we calculate x^* and R for the two models. We assume for simplicity that $b \simeq 1$. The results are

$$x^*_{\text{Wal}} = \sqrt{\frac{2z}{(\gamma-1)^2(\varepsilon-1)}}; \quad (38)$$

$$x^*_{\text{EW}} = \sqrt{\frac{2z}{(\phi-1)^2(\varepsilon-1)}}; \quad (39)$$

$$R_{\text{Wal}} = \frac{1+\varepsilon\gamma-\varepsilon}{\varepsilon(\varepsilon-1)(\gamma-1)^2}; \quad (40)$$

$$R_{\text{EW}} = \frac{\phi + [(\varepsilon-1)/\gamma\varepsilon][(1-a)\gamma+a][(1-a)(\gamma-1)-\phi]}{(\phi-1)^2(\varepsilon-1)}. \quad (41)$$

The expression for x^*_{EW} is identical to the one for x^*_{Wal} except that ϕ replaces γ. Efficiency wages increase nominal rigidity if $\phi < \gamma$, and the degree of nominal rigidity becomes large as the real wage becomes acyclical (ϕ approaches one). The effect of efficiency wages on R is more complex, but R_{EW} also becomes large as the real wage becomes acyclical.

As in Section IV, we can ask how much real rigidity is needed for large non-neutralities. For various parameter values, Table 3 shows the degree of real price rigidity, the private cost of non-adjustment to a 5% change in money, and the value of R in both the Walrasian and the efficiency wage model. In contrast to the customer markets example, the degree of real price rigidity is determined by parameters for which we know plausible values, and so we can ask whether the amount of real rigidity needed for substantial nominal rigidity is realistic.

TABLE 3

Efficiency Wage Model

	$1/(\gamma-1)=1/(\varepsilon-1)=0\cdot15$, $a=0\cdot50$					$1/(\gamma-1)=1/(\varepsilon-1)=1\cdot00$, $a=0\cdot50$			
	ϕ	π	*PC*	*R*		ϕ	π	*PC*	*R*
Wal	—	6·70	37·60	0·02	*Wal*	—	1·00	0·13	1·50
EW	2·00	1·00	0·84	0·40	*EW*	2·00	1·00	0·13	1·44
	1·50	0·50	0·21	1·44		1·50	0·50	0·03	4·50
	1·10	0·10	0·01	32·93		1·10	0·10	0·00	87·50
	1·05	0·05	0·00	130·19		1·05	0·05	0·00	337·50

	$1/(\gamma-1)=1/(\varepsilon-1)=0\cdot15$, $a=0$					$1/(\gamma-1)=1/(\varepsilon-1)=0\cdot15$, $a=1\cdot00$			
	ϕ	π	*PC*	*R*		ϕ	π	*PC*	*R*
Wal	—	6·70	37·60	0·02	*Wal*	—	6·70	37·60	0·02
EW	2·00	1·00	0·84	0·91	*EW*	2·00	1·00	0·84	0·26
	1·50	0·50	0·21	3·60		1·50	0·50	0·21	0·79
	1·10	0·10	0·01	89·15		1·10	0·10	0·01	14·56
	1·05	0·05	0·00	356·19		1·05	0·05	0·00	55·60

Note. Private cost is for a 5% change in money, and is measured as a percentage of revenue when prices are flexible.

As an empirically plausible base case, we assume that $\phi = 1\cdot1$—real wages are only slightly procyclical under efficiency wages—and $a = 0\cdot5$—variations in labour are divided equally between hours and employment.[17] We assume as above that the markup and labour supply elasticity are both 0·15. For these parameter values, the introduction of efficiency wages has dramatic effects. In a Walrasian labour market, the private cost of rigidity is a huge 38% of revenue, and R is a tiny 0·02.[18] But with efficiency wages, the private cost is less than one hundredth of a percent and R is 33. Intuitively, the private cost is small because, with nearly acyclical real wages, shifts in aggregate output have little effect on marginal cost, and so firms' desired price adjustments are small. As in Section IV, substantial nominal rigidity requires substantial real price rigidity: in our base case, introducing efficiency wages reduces π from 6·7 to 0·1. In this model, however, it is clear that this much real rigidity can arise from plausible underlying assumptions—in particular, the assumption that real wages are nearly acyclical.

VI. CONCLUSION

Rigidities in real wages and prices are not sufficient to explain real effects of nominal disturbances. In the absence of nominal frictions, prices adjust fully to nominal shocks regardless of the degree of real rigidity. Small costs of adjusting nominal prices are also not enough to explain important non-neutralities. With no real rigidities, these frictions cannot prevent adjustment to sizable nominal shocks or cause nominal fluctuations to

17. Estimates of the cyclical behaviour of real wages vary, but many studies find that real wages are approximately acyclical (for example, Geary and Kennan (1982)). The choice of $a = 0\cdot5$ is based on the common finding (for example, Barksy and Miron (1989)) that at business cycle frequencies the elasticity of output with respect to employment is roughly two and the elasticity with respect to total man hours is roughly one.

18. $R = 0\cdot02$ implies that, with a Walrasian labour market, the private gains from adjustment are much greater than the social gains. An individual producer can greatly increase profits by cutting his price when the real wage is low, but society cannot realize similar gains: if all sellers cut their prices, then output rises and the real wage rises, which greatly reduces each seller's gain from adjustment.

have large welfare effects. This paper shows, however, that the *combination* of substantial real rigidity and small costs of nominal flexibility can lead to large real effects of money. We derive this result both in general and for two specific examples of real rigidities.

We do not fully resolve whether the degrees of real rigidity needed for large nominal rigidities are realistic. In our customer markets model, the degree of real rigidity depends on the sharpness of the asymmetry in demand, a parameter for which we do not know realistic values. In our efficiency wage model, real rigidity is tied to the cyclical behaviour of the real wage, for which there is evidence, but the microeconomic foundations of this behaviour are not settled. Further research on real rigidities is therefore crucial for strengthening the foundations of Keynesian economics. This paper shows that better explanations for real rigidities will yield better explanations for nominal rigidities as well.

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