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REAL RIGIDITIES AND THE NON-NEUTRALITY OF MONEY

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ABSTRACT

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 several specific sources of real rigidity: costs of adjusting real prices, asymmetric demand arising from imperfect information, and efficiency wages.

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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, insider/outsider models, inventory models, and theories of countercyclical markups under imperfect competition.[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.

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

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. Recent research shows that in principle the nominal rigidities caused by small costs of flexibility can be large (Mankiw, 1985; Blanchard and Kiyotaki, 1987; Ball and Romer, 1987a). In these models, however, small frictions have large effects only for very implausible parameter values; for example, labor supply must be highly elastic. For plausible parameter values, nominal rigidity has large private costs. As a result, firms and workers choose only a small degree of rigidity, and nominal shocks have only small real effects.

We reverse these results by adding real rigidities to a model with a cost of changing nominal prices. Both the degree of nominal rigidity caused by this friction and the resulting welfare loss are increasing in the degree of real rigidity. Substantial real rigidity implies a large amount of nominal rigidity even if the cost of changing prices is small.[2,3]

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 chang-

[2]Akerlof and Yellen (1985) show that nominal rigidity can result from "near-rational" behavior rather than costs of adjusting prices. Our central point carries over to their model: a greater degree of real rigidity implies that a greater degree of nominal rigidity can arise from a given departure from full rationality.

[3]Blanchard (1987a, b) also argues that real rigidities increase the real effects of nominal disturbances.

ing 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.

The remainder of the paper consists of six 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 cost of changing prices -- a "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 three sections illustrate the general relation between real and nominal rigidity. In each case, we add a specific source of real rigidity to the model of Section III and show that large non-neutralities can result. Section IV presents our simplest example, in which we add an ad hoc cost of adjusting real prices to the small fixed cost of adjusting nominal prices. Section V presents a model in which the real rigidities have firm microeconomic foundations. Specifically, we combine our basic model with a model of imperfect information and customer markets based on Stiglitz (1979, 1984) and Woglom (1982). Real rigidity arises from an asymmetry in the demand curve facing a seller. Finally, Section VI considers real wage rigidity that arises when firms pay efficiency wages. This example is motivated by the common belief that the labor market is an important source of real rigidities.

Section VII 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.[4] In addition, there is a small cost, z, of changing nominal prices -- the menu cost. Thus agent i's utility is given by

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

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[4] 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 below is that if all agents (or, since the economy is large, all but one) choose the same price, then P equals this price.

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 labor. We also, however, consider the case in which farmers hire each other in a labor 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 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:

$$(2) \qquad Y = \frac{M}{P}$$

where M is the nominal money stock.[5] Substituting (2) into (1) yields

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

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[5]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, 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.

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 aggregate demand. Part C derives the degree of nominal rigidity, defined by the largest monetary shock to which prices do not adjust. Under broad (although not universal) 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 condition with respect to M/P yields

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

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 response of an agent's desired price to changes in real money, which shift aggregate demand.

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. Of the specific sources of real rigidity that we consider in later sections, two raise $-W_{22}$ and one lowers W_{12}.

C. The Equilibrium Degree of Nominal Rigidity

We measure nominal rigidity through the following experiment. Assume that M is random. The distribution of M is continuous, symmetric around one, increasing for M<1, and decreasing for M>1. All agents know the distribution. Each agent sets a nominal price before M is realized and then, after observing M, 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 an equilibrium. This range is symmetric around one, $(1-x^*, 1+x^*)$; x^* is our measure of nominal rigidity. We show that a broad class of changes in $W(\cdot)$ that increase real rigidity raise x^* as well. The derivation of x^* is similar to calculations in Ball and Romer (1987a, b), and so here we simply sketch the analysis.

A preliminary step is to determine the price, P_0, that agents set before they observe the money supply. This is the aggregate price level if agents do not adjust ex post -- that is, if the money supply falls within $(1-x^*, 1+x^*)$. One can show that P_0 can be approximated by

(5) $$\frac{1}{P_0} \approx 1 - \frac{W_{211}}{2W_{21}}\hat{\sigma}_M^2(x^*) ,$$

where we again evaluate derivatives at (1,1), and where $\hat{\sigma}_M^2(x^*)$ is the variance of M conditional on $M\epsilon(1-x^*,1+x^*)$. Although P=M when prices are flexible, P_0 differs from one, the mean of M, if $W_{211}\neq 0$ -- certainty equivalence fails if utility is not quadratic.

We now determine when non-adjustment of prices after M is realized is a Nash equilibrium. We do so by comparing an agent's utility if he adjusts his price and if he does not, given that no other agent adjusts. If agent i maintains a rigid price of P_0 along with the others, then $D_i=0$, $M/P = M/P_0$, and $P_i/P = 1$. Thus the agent's utility is $W(\frac{M}{P_0}, 1)$. If the agent adjusts despite others' non-adjustment, then $D_i=1$. Since one agent's behavior does not affect the aggregate price level, M/P is still M/P_0. Finally, the agent sets P_i/P equal to P_i^*/P, the utility-maximizing level given M/P. Thus the agent's utility is $W(\frac{M}{P_0}, \frac{P_i^*}{P}) - z$.

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

(6) $$PC < z ,$$

$$PC = W(\frac{M}{P_0}, \frac{P_i^*}{P}) - W(\frac{M}{P_0}, 1) .$$

PC is the "private cost" of nominal rigidity: agent i's loss from not setting his relative price at the utility-maximizing level. According to (6), rigidity is an equilibrium if this loss is less than the menu cost. Approximating the private cost around (1,1) yields

(7) $$PC \approx \frac{-(W_{21})^2}{2W_{22}}x^2 ,$$

where $x \equiv M-1$. Equations (6) and (7) imply that rigidity is an equilibrium when M lies within $(1-x^*, 1+x^*)$, where

$$(8) \qquad x^* = \sqrt{\frac{-2W_{22}z}{(W_{21})^2}} .$$

We can now show the connection between real and nominal rigidity. Using the fact that $\pi = -W_{21}/W_{22}$, we can rewrite (8) as

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

If there is no nominal friction, then nominal prices are completely flexible regardless of the degree of real rigidity: $x^* \equiv 0$ if $z=0$. But for a positive menu cost, increasing real rigidity while holding constant W_{22} -- that is, decreasing π by decreasing W_{12} -- leads to greater nominal rigidity. As π approaches zero, the degree of nominal rigidity becomes arbitrarily large. Alternatively, using the definition of π we can rewrite (8) as

$$(10) \qquad x^* = \sqrt{\frac{2z}{\pi W_{12}}} .$$

According to (10), increasing real rigidity while holding constant W_{12} -- that is, lowering π by increasing $-W_{22}$ -- also increases nominal rigidity.

Thus an increase in real rigidity -- a fall in $-W_{12}/W_{22}$ -- caused by either a reduction in W_{12} or an increase in $-W_{22}$ leads to greater nominal rigidity. 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}.

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' behavior 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 forgoing it is smaller; thus a menu cost is sufficient to prevent adjustment for a wider range of shocks.[6]

D. The Welfare Losses from Nominal Rigidity

Since real rigidity increases nominal rigidity, it increases the economic fluctuations resulting from shocks to nominal aggregate demand. Keynesians believe not only that such fluctuations are large, but also that they are

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[6]Following Ball and Romer (1987b), we can compute the range of monetary shocks for which full adjustment of all prices is an equilibrium as well as the range for which rigidity is an equilibrium. Adjustment is an equilibrium for $|x|>x^{**}$, $x^{**}=\sqrt{2z/(-W_{22})}$. As our previous paper points out, for many specific models, $x^{**}<x^*$ -- that is, there is a range of shocks, $x^{**}<|x|<x^*$, for which both rigidity and flexibility are equilibria. Combining the expression for x^{**} with (9) yields $x^*/x^{**} = 1/\pi$. Thus multiple equilibria require sufficient real rigidity ($\pi<1$), and greater real rigidity increases the range of multiple equilibria. Intuitively, multiple equilibria arise from "strategic complementarity" in price-setting: an agent's desired nominal price depends positively on others' prices, and so adjustment by others increases his incentive to adjust. Real rigidity raises the degree of strategic complementarity -- when agents want stable real prices, their desired nominal prices are closely tied to others' prices.

highly inefficient -- and thus that reducing them through demand stabilization is highly desirable. We now show that real rigidities strengthen this view: greater real rigidity implies greater welfare losses from equilibrium nominal rigidity. As we show in the next section, this result is important because the clearest failure of menu cost models without real rigidities is an inability to generate fluctuations with significant welfare costs.

To simplify our welfare analysis, we modify the experiment of the previous section: following Ball and Romer (1987a), we assume that an agent must decide whether to pay the menu cost before he observes the money supply. If the agent pays, he can always adjust his price ex post; if he does not pay, his price is always rigid. In other words, the degree of nominal rigidity is a zero-one variable. As in our earlier paper, this simplification does not affect the qualitative results.

In this version of the model, one can show that (complete) rigidity is an equilibrium if

$$(11) \qquad PC < z, \qquad PC \simeq \frac{-(W_{21})^2}{2W_{22}}\sigma_M^2 .$$

Comparing (11) with (7) shows that $\sigma_M^2 = E[(M-1)^2]$ replaces $x^2 = (M-1)^2$ in the expression for the private cost. In choosing between rigidity and flexibility ex ante, agents compare the menu cost to the expected private loss from rigidity, which is increasing in the variance of money.

The welfare loss from equilibrium rigidity depends on the relation of PC to the "social cost" of rigidity: the difference between $E[W(\cdot)]$ when all agents pay the menu cost and when none pays. If no agent pays, then by reasoning similar to the derivation of (6), $E[W(\cdot)] = E[W(M/P_0,1)]$; P_0 is now given by

$$(12) \qquad \frac{1}{P_0} \simeq 1 - \frac{W_{211}}{2W_{21}}\sigma_M^2 .$$

If all agents pay the menu cost, then $M/P \equiv 1$ and $P_i/P \equiv 1$ (the equilibrium under flexible prices); thus $E[W(\cdot)] = W(1,1)$. These results imply that the social cost of rigidity is

$$(13) \qquad SC = W(1,1) - E[W(M/P_0, 1)]$$

$$\simeq \frac{W_1W_{211}-W_{11}W_{21}}{2W_{21}}\sigma_M^2 .$$

Combining (11) and (13) yields the ratio of the social to the private cost of rigidity:

$$(14) \qquad R = \frac{SC}{PC} = \frac{W_{22}(W_{11}W_{21} - W_1W_{211})}{(W_{21})^3} .$$

Recall that nominal rigidity is an equilibrium as long as the private cost does not exceed z. This implies that the largest possible social cost of equilibrium rigidity is R times z. Since the losses from rigidity disappear when $\sigma_M^2=0$, Rz is also the maximum gain from stabilizing nominal 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 (1987a), 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 aggregate demand, which harms all agents.

The size of R, like the degree of nominal rigidity, does not depend solely on the degree of real rigidity but is linked to it in important ways. 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 (W_{22} does not appear in the expression for SC). 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 it can affect the social cost as well. Nominal rigidity affects not only the variance of output, as we emphasize, but also the mean. This follows from the deviation of the price level under stickiness from the certainty equivalent level (see our 1987a paper for details). The effect of rigidity on mean output depends on W_{12} in a complicated way; as a result, reducing W_{12} has in general an ambiguous effect on R. In the specific models of this paper, however, the effect of rigidity on mean output is 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 SIMPLE YEOMAN FARMER MODEL

This section considers one example of the class of models studied above: the "yeoman farmer" model of Ball and Romer (1987a,b). Aside from imperfect competition and the menu cost, the model's assumptions are Walrasian. We show that both the degree of nominal rigidity and the welfare loss from rigidity are small for plausible parameter values; thus menu costs are not enough to produce large real effects of money. The model of this section is also the basis for Sections IV-VI: in each of these, we add a specific source of real rigidity to the model and show that large non-neutralities can result.

A. The Model[7]

The agents in this model are a continuum of farmers indexed by i and distributed uniformly between i=0 and i=1. Each farmer uses his own labor to produce a differentiated good, then sells this product and purchases the products of all other farmers. Farmer i's utility function is

$$(15)\qquad U_i = C_i - \frac{\varepsilon-1}{\gamma\varepsilon}L_i{}^{\gamma} - zD_i\ , \qquad C_i = [\int_{j=0}^{1} C_{ij}{}^{(\varepsilon-1)/\varepsilon}\, dj]^{\varepsilon/(\varepsilon-1)}$$

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, ε is the elasticity of substitution between any two goods ($\varepsilon>1$), and γ measures the extent of increasing marginal disutility of labor ($\gamma>1$). The coefficient on L_i is chosen so that equilibrium output neglecting menu costs is one, as in our general model.

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[7]See Ball and Romer (1987a) for a more detailed presentation of the model.

Farmer i has a linear production function:

$$(16) \qquad Y_i = L_i ,$$

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

$$(17) \qquad Y = \frac{M}{P} ,$$

where in this model

$$(18) \qquad Y = \int_{i=0}^{1} Y_i di \; ; \qquad P = [\int_{i=0}^{1} P_i^{1-\varepsilon} di]^{1/(1-\varepsilon)} .$$

P is the price index for consumption, C_i.

Equations (15)-(18) determine the demand for farmer i's product:

$$(19) \qquad Y_i^D = (\frac{M}{P})(\frac{P_i}{P})^{-\varepsilon} .$$

Farmer i's consumption equals his real revenues:

$$(20) \qquad C_i = \frac{P_i Y_i}{P} .$$

Substituting (19) and (20) into (15) yields the specific form of $W(\cdot)$ in this model:

$$(21) \qquad U_i = (\frac{M}{P})(\frac{P_i}{P})^{(1-\varepsilon)} - \frac{\varepsilon-1}{\gamma\varepsilon}(\frac{M}{P})^{\gamma}(\frac{P_i}{P})^{-\gamma\varepsilon} - zD_i$$

$$\equiv W(\frac{M}{P}, \frac{P_i}{P}) .$$

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 (21), evaluating at (1,1), and substituting into (8) and (14) yields

$$(22) \qquad x^* = \sqrt{\frac{2(1+\gamma\varepsilon-\varepsilon)z}{(\varepsilon-1)(\gamma-1)^2}}\ ; \quad R = \frac{(1+\varepsilon\gamma-\varepsilon)^2}{\varepsilon(\varepsilon-1)(\gamma-1)^2} \quad (R > 1)\ .$$

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 (that is, x^* need not be large). 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 five percent 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.[8] The private cost equals the menu cost needed to prevent adjustment to the shock -- that is, to make x^* greater than .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 five percent change in money implies a five percent 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 labor. The table presents the private cost and R as functions of $1/(\varepsilon-1)$, the markup of price over marginal cost, and $1/(\gamma-1)$, farmers' labor supply elasticity.

[8]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 always one.

We focus on a base case in which, using evidence from empirical studies, we take .15 as the value of the markup and .15 again as the labor supply elasticity; these numbers imply $\epsilon=\gamma=7.7$.[9] For these values, the private cost of rigidity is seven tenths of a percent of revenue, which appears non-negligible. (If the change in money is three rather than five percent, the private cost is three tenths of a percent of revenue.) 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.[10] In any case, the welfare result is very clear. When both the markup and the labor supply elasticity are .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=1.2 and small menu costs imply that this loss is

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[9]For evidence on markups, see Scherer (1980); for labor supply elasticities, see Killingsworth (1983).

[10]How large are the costs of adjusting prices in actual economies? In many cases, the cost of physically changing a price (for example, by replacing a price tag) seem <u>very</u> small. But the lost convenience of fixing prices in nominal terms -- the cost of learning to think in real terms, and of computing the nominal price changes corresponding to desired real price changes -- may be larger. The costs of adjusting nominal wages appear larger than the costs of adjusting prices, especially if adjustment requires union-management negotiations. On the other hand, it appears relatively inexpensive to increase wage flexibility through greater indexation. Finally, if we follow Akerlof and Yellen in interpreting the menu cost as a departure from full rationality, it seems plausible that these departures involve losses significantly greater than the cost of a price tag.

small.[11]

Table 1 shows that it is difficult to reverse these results. Since the private cost of rigidity is decreasing in both the markup and the labor supply elasticity, we consider the case in which each is 1.0; this is a generous upper bound for both. In this case, the private cost of non-adjustment to a five percent change in money is .04% of revenue, which is perhaps trivial. But R=4.5 -- the welfare cost of the business cycle is still only four and a half times the menu cost. Only outlandish parameter values yield large values of R -- for example, a markup of one and a labor supply elasticity of ten imply R=72.

Intuitively, the crucial problem for the model is that labor supply appears to be inelastic (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.

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[11]Two changes in the model would strengthen these results. First, following Ball and Romer (1987a), we could introduce risk aversion in consumption. Assuming constant relative risk aversion utility with a risk aversion coefficient of four (a typical estimate; see for example Mankiw, 1981) raises the private cost of rigidity to 1.2% of revenue and reduces R to 1.1. Second, by assuming self-employment, we have implicitly assumed that labor is immobile. As we describe in Section VI, introducing labor mobility increases the private gains from price adjustment. If mobility is perfect, the effects are dramatic: the private cost of non-adjustment is 38% of revenue and R is 0.015.

IV. AN AD HOC MODEL OF REAL RIGIDITY

This section presents the first of three examples in which we add a specific source of real rigidity to the yeoman farmer model. Here, we add real rigidity as simply as possible by assuming ad hoc that real prices are costly to change.

A. The Implications of Costs of Adjusting Real Prices

Modify the utility function, (15), to be

$$(23)\quad U_i = C_i - \frac{\varepsilon-1}{\gamma\varepsilon}L_i^{\gamma} - zD_i - k\left(\frac{P_i}{P} - 1\right)^2 ,$$

where k is a non-negative constant. With this change, equation (21) becomes

$$(24)\quad U_i = \left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{(1-\varepsilon)} - \frac{\varepsilon-1}{\gamma\varepsilon}\left(\frac{M}{P}\right)^{\gamma}\left(\frac{P_i}{P}\right)^{-\gamma\varepsilon} - zD_i - k\left(\frac{P_i}{P} - 1\right)^2$$

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

Equation (23) adds a quadratic cost of adjusting real prices to the fixed cost of adjusting nominal prices. (Each farmer begins with a real price of one because $P_i=P_0=P$ before the money stock is observed.) Following Rotemberg (1982), we could interpret $k(\frac{P_i}{P}-1)^2$ as the cost of upsetting customers through unstable prices; this cost might be lost sales in a future period that is not included explicitly in the model.[12] Alternatively, we could interpret $k(\frac{P_i}{P}-1)^2$ as the cost of violating a social custom about "fair" prices (see Akerlof, 1980, and Romer, 1984).[13]

Substituting the appropriate derivatives of (24) into the definition of π yields

$$(25) \qquad \pi = \frac{(\gamma-1)(\varepsilon-1)}{(\varepsilon-1)(1+\gamma\varepsilon-\varepsilon)+2k}; \quad \frac{\partial\pi}{\partial k} < 0, \quad \lim_{k\to\infty} \pi = 0 .$$

Not surprisingly, the degree of real rigidity is increasing in the cost of adjusting real prices, and real prices become completely rigid as the cost approaches infinity.

To determine the relation between real and nominal rigidity, we substitute the derivatives of (24) into (8) and (14):

$$(26) \qquad x^* = \sqrt{\frac{2[(\varepsilon-1)(1+\gamma\varepsilon-\varepsilon)+2k]z}{(\varepsilon-1)^2(\gamma-1)^2}} ;$$

$$(27) \qquad R = \frac{1+\varepsilon\gamma-\varepsilon}{\varepsilon(\varepsilon-1)(\gamma-1)^2}[(\varepsilon-1)(1+\gamma\varepsilon-\varepsilon) + 2k] .$$

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[12]Rotemberg assumes that customers dislike instability in nominal prices, and therefore specifies a quadratic cost of adjusting nominal prices. In the absence of money illusion, however, customers care only about real prices. We adopt a quadratic functional form because presumably large real price changes upset customers more than small changes. In contrast, it is realistic to assume that the cost of adjusting a nominal price is fixed: the cost of replacing a price tag does not depend on the new price.

[13]Social customs can be modeled more rigorously by assuming that consumers receive disutility from purchasing the products of unfair sellers. For example, product-specific taste shifters can be added to the utility function, with the taste shifter for product i depending negatively on $(P_i/P - 1)^2$. In this case, a firm's demand decreases if it charges an unfair price. One can show that the implications for price rigidity are similar to those of our ad hoc model.

Inspection of (26) and (27) shows that both x^* and R are increasing in k, and that both approach infinity as k approaches infinity. Thus increasing real rigidity by introducing costs of changing real prices can lead to large nominal rigidities. In terms of our general model, one can show that increasing k lowers π by raising $-W_{22}$ -- making utility more concave in prices -- while leaving W_{12} unchanged. As shown in Section II, increasing real rigidity in this way always produces greater nominal rigidity.

B. How Much Real Rigidity is Necessary?

Section III showed that without costs of changing real prices, 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 five percent change in money) and R for various values of the markup, the labor supply elasticity, and the degree of real rigidity π. Note that, given the other parameters, there is a one-to-one relation between π and k; we present results in terms of π because k has little economic meaning. Since the results about the size of 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 k=0 -- real prices are costless to change, so the model reduces to the one in Section III -- a markup of .15 and a labor supply elasticity of .15 imply π=.127 and (as shown above) R=1.2. Increasing k so that π falls to .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. (π=.05 combined with a markup and labor supply elasticity of one implies R=30.) Larger reductions in π produce better results: π=.01 implies R=15 for a markup and labor supply elasticity of .15 (and R=150 for a markup and elasticity of one), and π=.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. Our ad hoc model does not tie the degree of real rigidity to parameters of tastes or technology that we can estimate. The literature on customer markets, social customs, and so on suggests that the costs of adjusting real prices may be large -- certainly there is no presumption that they are trivial, as with the costs of adjusting nominal prices. Research has not gone far enough, however, to produce quantitative estimates of the resulting real rigidity. We return to the issue of how much real rigidity can be generated by realistic models in the following sections.

V. IMPERFECT INFORMATION AND CUSTOMER MARKETS

A. Overview

This section studies a version of our yeoman farmer model in which real price rigidity is based on microeconomic foundations. 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 <u>not</u> attract other firms' customers, because they do not observe the lower price.

To introduce this asymmetry in demand, we modify our basic model by assuming that each of the goods in the economy 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.)

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. Finally, Part E demonstrates the link between real and nominal rigidity in this example.

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 of 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 then, after M is revealed, can adjust by paying 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, (15), to be

$$(28) \qquad U_i = AC_i - BL_i^{\gamma} - zD_i \, ,$$

where

$$(29) \qquad C_i = \{ \int_{j=0}^{1} [(\theta_{ij})^{D(ij)} C_{ij}]^{(\varepsilon-1)/\varepsilon} \, dj \}^{\varepsilon/(\varepsilon-1)} \, .$$

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.[14] 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 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.

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[14]The definitions of A and B are:

$$A = [F(1) + \int_{\theta=1}^{\infty} \theta^{\varepsilon-1} f(\theta) d\theta]^{1/(1-\varepsilon)} ;$$

$$B = \frac{(\varepsilon-1)A^{1-\varepsilon}+f(1)}{[\varepsilon A^{1-\varepsilon}+f(1)]\gamma} ,$$

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

C. Product Demand

The first step in studying this version of the model is to derive the demand curve facing an individual seller. We focus on the case in which all other sellers in the economy charge a real price of one; the analysis below requires only the results for this case.

A farmer 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. The utility function, (28), and the assumption that others' real prices are one imply that a customer of farmer i remains if[15]

$$(30) \qquad P_i/P < \theta .$$

One can show that if a customer stays, his demand for the farmer's product is

$$(31) \qquad (A\theta)^{(\varepsilon-1)}\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right) .$$

Equations (30) and (31) imply that total demand from customers who stay is

$$(32) \qquad \int_{\theta=P_i/P}^{\infty} (A\theta)^{(\varepsilon-1)}\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right)f(\theta)d\theta .$$

Customers of other sellers of farmer i's product also use the rule in (30) (with the others' prices replacing P_i) to decide whether to leave. Since we assume that the other sellers charge a real price of one, their customers switch if $\theta<1$; thus the proportion that leaves is F(1). Our symmetry assump-

[15]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.

tions imply that 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 (31) with θ replaced by one, since $\theta^{D(ij)} \equiv 1$ for buyers who switch sellers. Combining these results, the total demand from new customers is

$$(33) \qquad A^{\varepsilon-1}F(1)\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right) .$$

Combining (32) and (33), farmer i's total demand is

$$(34) \qquad Y_i^D = \{F(1) + \int_{\theta=P_i/P}^{\infty} \theta^{\varepsilon-1}f(\theta)d\theta\} A^{\varepsilon-1}\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right)$$

$$\equiv A^{\varepsilon-1}h\left(\frac{P_i}{P}\right)\left(\frac{P_i}{P}\right)^{-\varepsilon}\left(\frac{M}{P}\right) .$$

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

$$(35) \qquad \eta \equiv -\frac{\partial \ln Y_i^D}{\partial \ln(P_i/P)}\bigg|_{(P_i/P)=1} = \varepsilon + \frac{f(1)}{h(1)} ;$$

$$\rho \equiv -\frac{\partial^2 \ln Y_i^D}{\partial \ln(P_i/P)^2}\bigg|_{(P_i/P)=1} = \eta\frac{f(1)}{h(1)} + \frac{f'(1)}{h(1)} .$$

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.

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 does not attract new customers, but it saves 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 $f'(1)>1$.

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 neighborhood of one. In this case, $\eta=\varepsilon$, $\rho=0$, and the demand function reduces to (19), the symmetric function in the basic model. Small changes in a farmer's price do not affect his number of customers, and so price affects demand only because customers substitute the farmer's product for other goods. The second case is $f(\theta)=0$ for $\theta<1$ and $f'(1)\rightarrow\infty$. This implies $\rho\rightarrow\infty$: the demand curve is kinked, as in Stiglitz and Woglom. In this case, all customers remain as long as $P_i/P \leq 1$, but a non-negligible proportion leaves as soon as the price rises above one.

D. Real Rigidity

Substituting the demand equation, (34), into the utility function, (28), yields W(•) for this model:

$$(36)\quad U_i = A^{(\varepsilon-1)}(\frac{M}{P})h(\frac{P_i}{P})(\frac{P_i}{P})^{(1-\varepsilon)} - A^{\gamma(\varepsilon-1)}B[h(\frac{P_i}{P})]^{\gamma}(\frac{M}{P})^{\gamma}(\frac{P_i}{P})^{-\gamma\varepsilon}$$

$$- zD_i$$

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

Substituting the appropriate derivatives of W(•) into the definition of π yields

$$(37)\qquad \pi = \frac{\eta(\gamma-1)(\eta-1)}{\eta(\eta-1)(1+\gamma\eta-\eta)+\rho}\ ; \qquad \frac{\partial\pi}{\partial\rho} < 0\ ; \quad \lim_{\rho\to\infty} \pi = 0\ .$$

According to (37), 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 (36) into (8) and (14) yields

$$(38) \qquad x^* = \sqrt{\frac{2[(\eta-1)(1+\gamma\eta-\eta)+(\rho/\eta)]z}{(\gamma-1)^2(\eta-1)^2}}\ ;$$

$$(39) \qquad R = \frac{(1+\gamma\eta-\eta)^2}{\eta(\eta-1)(\gamma-1)^2} + \frac{\rho}{\eta^2(\eta-1)(\gamma-1)} .$$

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.[16] In terms of our general model, one can show that increases in ρ raise x^* and R because (like increases in k in the previous section) 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.

As in Section III, one can compute the private cost of nominal rigidity and R for various parameter values. The main qualitative result is the same as before: a large degree of real rigidity is necessary for a large R. It is again difficult to determine how much real rigidity is realistic, because we do not know realistic values for ρ, the sharpness of the bend in the demand

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[16]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 (as we argue in note 10 above) amounts to a small cost of nominal flexibility.

curve.

VI. THE LABOR MARKET AND REAL WAGE RIGIDITY

A. Discussion

For simplicity, the models of the previous sections suppress the labor market and study the implications of real price rigidity arising from product market imperfections. Traditionally, however, macroeconomists have viewed labor market imperfections as central to aggregate fluctuations. Motivated by this view, we now present a model with a labor market in which rigidity in firms' real prices is caused by rigidity in their real wages. Real wage rigidity arises from efficiency wage considerations.[17]

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 labor supply, which gives farmers strong incentives to stabilize their employment by adjusting prices. The analogue when firms hire workers in a Walrasian labor market is that inelastic labor supply implies highly procyclical real wages -- large wage increases are needed to elicit more work. 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

[17]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.

wage models is that firms set wages above the market clearing level. Since real wages are not tied directly to labor supply, inelastic labor supply need not imply procyclical real wages.[18]

A second motivation for this section is the difficulty in earlier sections of determining how much real price rigidity is realistic. This difficulty reflects uncertainty about the values of key parameters (the cost of adjusting real prices and the sharpness of the bend in demand). 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.

Our analysis of efficiency wages is tentative because research has not yet clearly established the implications of efficiency wages for the cyclical behavior of real wages. In early efficiency wage models, in which workers' effort depends only on their wages (such as Solow, 1979), wages are completely acyclical. More recent "shirking" models (such as Shapiro and Stiglitz, 1984) imply procyclical real wages: when unemployment is high, workers are fearful of being fired, and so firms can reduce wages without inducing shirking. Blanchard (1987b) argues, however, that real wages are less procyclical when

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[18]In emphasizing the labor market, we depart from currently popular macroeconomic theories that focus on the product market. For example, Hall (1986) argues that the combination of constant marginal cost and imperfect competition leads to slow adjustment of the economy to shocks. These product market theories are incomplete because they do not explain how their assumptions are consistent with labor market behavior -- for example, how marginal cost can be acyclical despite inelastic labor supply.

firms pay efficiency wages than in a Walrasian labor market, and Sparks (1986) presents a modification of the shirking model in which real wages are acyclical. These results appear plausible because, as noted above, efficiency wages break the link between wages and labor supply that causes highly procyclical real wages. But at present, the robustness of these results and the size of the effect of efficiency wages on the cyclicality of real wages are unclear. In what follows, we simply assume that real wages are substantially less procyclical -- that is, more rigid in the face of demand fluctuations -- than in a clearing market.[19]

B. A Model

We now present an example to illustrate the potential importance of efficiency wages.[20] Since efficiency wages are a labor market phenomenon, a preliminary step is to modify our basic model by assuming that farmers work for each other rather than for themselves. For the moment, we assume that the labor market is Walrasian. Farmers have two sources of income, profits from their own farms and wages from working for others. Using the production function, (16), and the product demand equation, (19), one can derive the follow-

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[19]In all efficiency wage models, real wages are rigid in the sense that they are set above market-clearing levels. This is not, however, the relevant type of real rigidity. As throughout the paper, large real effects of money require real rigidity in the sense of small responses to demand shifts.

[20]Akerlof and Yellen (1985) also present a model that combines a small nominal friction ("near-rationality") with efficiency wages. They do not, however, ask how the real rigidity resulting from efficiency wages affects the size of the real effects of money. They introduce efficiency wages so that nominal shocks affect involuntary unemployment as well as employment and output.

ing expression for a farmer's utility:

$$(40)\quad U_i = wL_i + \left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{(1-\varepsilon)} - w\left(\frac{M}{P}\right)\left(\frac{P_i}{P}\right)^{-\varepsilon} - \frac{\varepsilon-1}{\gamma\varepsilon}L_i{}^{\gamma} - zD_i ,$$

where w is the real wage. The first term in (40) is the farmer's labor income; the second (as in the basic model) is the revenue from his farm; the third is the wage bill he pays; and the fourth is the disutility from the labor he supplies. Deriving a labor supply function from (40) and combining it with the production function and our assumption that Y = M/P, we obtain

$$(41)\qquad w = \frac{\varepsilon-1}{\varepsilon}\left(\frac{M}{P}\right)^{\gamma-1} .$$

Equation (41) describes the cyclical behavior of real wages with a Walrasian labor market. Finally, (40) and (41) lead to the form of W(•) for this case:

$$(42)\qquad W_{Wal} = \frac{\varepsilon-1}{\varepsilon}\left(\frac{M}{P}\right)^{\gamma}\left[1-\left(\frac{P_i}{P}\right)^{-\varepsilon}\right] + \frac{M}{P}\left(\frac{P_i}{P}\right)^{1-\varepsilon} - \frac{\varepsilon-1}{\gamma\varepsilon}\left(\frac{M}{P}\right)^{\gamma} .$$

We now introduce efficiency wages. We simply assume that efficiency wage considerations lead to wages that obey

$$(43)\qquad w = \beta\frac{\varepsilon-1}{\varepsilon}\left(\frac{M}{P}\right)^{\phi-1} ,\qquad \beta>1,\quad 1<\phi<\gamma .$$

The functional form of (43) is chosen for comparability with (41). We can interpret (43) as giving the wage needed to prevent workers from shirking. $\beta>1$ implies that in the vicinity of the no-shock equilibrium, wages are set above the market-clearing level, and so suppliers of labor are rationed. (For simplicity, we assume below that β is close to one). Since workers are off their labor supply curves, the wage is no longer tied to γ, which determines the labor supply elasticity. $\phi<\gamma$ means that wages respond less to demand shifts than in a Walrasian labor market -- in other words, as in Blanchard the "no shirking condition" is flatter than the labor supply curve.

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

$$(44)\qquad E_i = (L_i^D)^a ;$$

$$(45)\qquad H_i = (L_i^D)^{1-a} , \qquad 0<a<1 ,$$

where E_i is the number of workers hired by farmer i, H_i is hours per worker, and $L_i^D = E_i H_i$ is the amount of labor 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(•) is a farmer's expected utility given his probability of employment. Since the size of the labor force is one, this probability is equal to E_i (equation (44)). The farmer's utility is determined by (40) with the wage given by (43) and the farmer's labor supply equal to H_i (equation (45)) when employed and zero when unemployed. Combining these results and using the fact that $L_i^D = Y_i = \frac{M}{P}$ yields

$$(46)\qquad W_{EW}(\frac{M}{P}, \frac{P_i}{P}) = \beta\frac{\varepsilon-1}{\varepsilon}(\frac{M}{P})\phi[1-(\frac{P_i}{P})^{-\varepsilon}] + \frac{M}{P}(\frac{P_i}{P})^{1-\varepsilon}$$

$$- \frac{\varepsilon-1}{\gamma\varepsilon}(\frac{M}{P})(1-a)\gamma+a .$$

C. Real and Nominal Rigidity

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

$$(47)\qquad \pi_{Wal} = \gamma - 1 ; \qquad \pi_{EW} = \phi - 1 .$$

Our assumption that real wages are more rigid under efficiency wages, $\phi<\gamma$, implies that 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 our earlier examples, in which real rigidity arises from a higher $-W_{22}$. Intuitively, efficiency wages do not affect W_{22} because they do not make changes in a firm's real price more costly. Instead, they reduce the responses of firms' desired prices to demand shifts because they reduce the effects of demand on the determinants of the desired price. Specifically, the desired price is proportional to marginal cost; since efficiency wages make real wages less responsive to aggregate demand, they make marginal cost less responsive.

To see the implications of efficiency wages for nominal rigidity, we calculate x^* and R for the two models. We assume for simplicity that $\beta\approx1$ (this implies that the no-shock level of employment under efficiency wages is close to the level in a Walrasian labor market). The results are

$$(48) \qquad x^*_{Wal} = \sqrt{\frac{2z}{(\gamma-1)^2(\varepsilon-1)}} ;$$

$$(49) \qquad x^*_{EW} = \sqrt{\frac{2z}{(\phi-1)^2(\varepsilon-1)}} ;$$

$$(50) \qquad R_{Wal} = \frac{1+\varepsilon\gamma-\varepsilon}{\varepsilon(\varepsilon-1)(\gamma-1)^2} ;$$

$$(51) \qquad R_{EW} = \frac{\phi+[(\varepsilon-1)/\gamma\varepsilon][(1-a)\gamma+a][(1-a)(\gamma-1)-\phi]}{(\phi-1)^2(\varepsilon-1)} .$$

The expression for x^*_{EW} is identical to the one for x^*_{Wal} except that ϕ replaces γ. Efficiency wages increase nominal rigidity (since $\phi<\gamma$), 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.[21]

As in previous sections, we now 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 five percent change in money, and the value of R in both the Walrasian and the efficiency wage model. In contrast to our previous examples, the degree of real price rigidity is determined by a parameter for which we know plausible values, and so we can ask whether the amount of real rigidity needed for substantial nominal rigidity is realistic.

As an empirically plausible base case, we assume that ϕ=1.1 -- real wages are only slightly procyclical under efficiency wages -- and a=.5 -- variations in labor are divided equally between hours and employment.[22] We assume as

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[21]While R_{EW} is much larger than R_{Wal} for plausible parameter values (see below), R_{Wal} is larger for some parameter values. This ambiguity arises because moving from the Walrasian to the efficiency wage model reduces $-W_{11}$, which implies smaller social costs of rigidity, as well as reducing W_{12}. Intuitively, rigidity is less costly under efficiency wages because the resulting output fluctuations arise partly from fluctuations in employment; in the Walrasian model, fluctuations arise entirely from changes in hours per worker. Fluctuations in employment imply fluctuations in each individual's probability of employment, which are costless on average because expected utility is linear in this probability. Fluctuations in hours are costly because utility is concave in hours.

[22]Estimates of the cyclical behavior of real wages vary, but many studies find that real wages are approximately acyclical (for example, Geary and Kennan, 1982). The choice of a=1/2 is based on the common finding (for example, Barsky and Miron, 1987) that at business cycle frequencies the elasticity of output with respect to employment is roughly two and the elasticity with respect to total manhours is roughly one.

above that the markup and labor supply elasticity are both .15. For these parameter values, the introduction of efficiency wages has dramatic effects. In a Walrasian labor market, the private cost of rigidity is a huge 38% of revenue, and R is a tiny .02.[23] But with efficiency wages, the private cost is less than one hundredth of a percent and R is 33. As in our other models, substantial nominal rigidity requires substantial real price rigidity -- in our base case, introducing efficiency wages reduces π from 6.7 to .1. But in this model, it is clear that this much real rigidity can arise from plausible underlying assumptions -- in particular, the assumption that real wages respond little to aggregate demand.

There are two caveats concerning these results. First, the value of R is quite sensitive to moderate changes in parameter values -- for example, if ϕ is raised from 1.1 to 1.5, R drops from 33 to 1.4. Second, and most impor-

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[23]Note that nominal prices are much more flexible with a Walrasian labor market than in the self-employment model of Section III -- the private cost of rigidity is much larger and R is much smaller. These results reflect the greater flexibility of real prices in the Walrasian model: for our base case, π=6.7 for the Walrasian model and π=.13 with self-employment. Intuitively, the private gains from price adjustment are large with a Walrasian labor market because when output falls (for example) the real wage is low. Since a producer can hire as much labor as he wants at this wage, he can greatly increase profits by cutting his price and increasing output. With self-employment, the gains from increasing output are smaller because a producer faces his own upward-sloping labor supply curve. This difference in incentives to adjust is very large if, as we assume, labor supply is inelastic: in this case, when output is low a producer faces a very low real wage in a Walrasian market but very steep labor supply under self-employment. Finally, note that R=.02 implies that, with a Walrasian labor market, the private gains from adjustment are much greater than the social gains. While an individual producer can greatly increase profits by cutting his price when the real wage is low, 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.

tant, while we have tied the degree of real rigidity to a parameter for which we know plausible values -- the cyclical sensitivity of real wages -- it is a parameter of aggregate economic behavior, not a microeconomic parameter of tastes or technology. We have not determined whether reasonable microeconomic assumptions can produce the assumed real wage behavior given the rest of our model. This reflects the fact that research has not completely determined how efficiency wages affect the cyclicality of real wages, and highlights the importance of future work on this issue. Our results simply show that if efficiency wages greatly reduce the responsiveness of real wages to demand, then they explain large nominal rigidities.

VII. CONCLUSIONS

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 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.

To review the explanation for this result, non-adjustment of prices to a nominal disturbance is an equilibrium when no price setter wants to adjust his price if others do not adjust. But non-adjustment to a nominal shock when others' prices are fixed implies non-adjustment of a real price to a change in real demand. Real rigidity means that a price setter desires only a small price change when demand shifts. In the absence of nominal frictions, a small desired change implies that non-adjustment is not an equilibrium. But since the cost of forgoing a small adjustment is small, a small "menu cost" is sufficient to make rigidity an equilibrium.[24]

We demonstrate the connection between real and nominal rigidity in a general class of models of imperfectly competitive price setters. In addition, we present models in which real rigidities arise from three specific sources: an ad hoc cost of changing real prices, imperfect information and customer markets, and efficiency wages. For each model, we find that a large degree of nominal rigidity arises only if the degree of real rigidity is large. We do not fully resolve whether the necessary amount of real rigidity is realistic. This requires development of models of real rigidities in which the degree of rigidity is derived from microeconomic parameters for which we know plausible values.

Strengthening the foundations of Keynesian economics requires further research into real rigidities. The point of this paper is that, along with small nominal frictions, real rigidities can lead to large nominal rigidities. Thus as we develop better explanations for real rigidities, we gain better ex-

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[24]Thus, for example, Keynes's argument that workers' concern for relative wages can lead to nominal wage rigidity is correct if amended slightly. Concern for relative wages is likely to reduce but not completely eliminate a firm's desired adjustment to a nominal shock. Keynes is correct if there is a small cost to prevent firms from making small adjustments.

planations for nominal rigidities as well.

REFERENCES

Akerlof, George A. "A Theory of Social Custom, of Which Unemployment May Be One Consequence." Quarterly Journal of Economics 94 (1980): 749-775.

_______ and Yellen, Janet L. "A Near-Rational Model of the Business Cycle, with Wage and Price Inertia." Quarterly Journal of Economics 100 (1985): 823-838.

Azariadis, Costas. "Implicit Contracts and Underemployment Equilibria." Journal of Political Economy 83 (1975): 1183-1202.

Baily, Martin Neil. "Wages and Unemployment under Uncertain Demand." Review of Economic Studies 41 (1974): 37-50.

Ball, Laurence, and Romer, David. "Are Prices Too Sticky?" NBER Working Paper #2171, February 1987. (1987a)

_______ and _______. "Sticky Prices As Coordination Failure." NBER Working Paper #2327, July 1987. (1987b)

Barsky, Robert, and Miron, Jeffrey. "The Seasonal Cycle and the Business Cycle." Mimeo, University of Michigan, June 1987.

Bils, Mark. "Pricing in a Customer Market." Rochester Center for Economic Research Working Paper No. 30, revised Summer 1986.

_______. "Cyclical Pricing of Durable Luxuries." Rochester Center for Economic Research Working Paper No. 83, May 1987.

Blanchard, Olivier J. "Aggregate and Individual Price Adjustment." Brookings Papers on Economic Activity 1987-1: 57-109. (1987a)

_______. "Why Does Money Affect Output?" Handbook of Monetary Economics, Benjamin Friedman and Frank Hahn, eds. Amsterdam: North Holland, forthcoming. (1987b)

_______ and Kiyotaki, Nobuhiro. "Monopolistic Competition and the Effects of Aggregate Demand." American Economic Review 77 (1987): 647-666.

Blinder, Alan. "Inventories and Sticky Prices." American Economic Review 72 (1982): 334-348.

Bulow, Jeremy I. and Summers, Lawrence H. "A Theory of Dual Labor Markets with Applications to Industrial Policy, Discrimination, and Keynesian

Unemployment." Journal of Labor Economics 4 (1986): 376-414.

Geary, Patrick and Kennan, John. "The Employment-Real Wage Relationship: An International Study." Journal of Political Economy 90 (1982): 854-871.

Hall, Robert E. "Market Structure and Macroeconomic Fluctuations." Brookings Papers on Economic Activity 1986-2: 285-338.

Killingsworth, Mark. Labor Supply. Cambridge: Cambridge University Press, 1983.

Lindbeck, Assar and Dennis Snower. "Wage Setting, Unemployment, and Insider-Outsider Relations." American Economic Review 76 (May 1986): 235-239.

Mankiw, N. Gregory. "The Permanent Income Hypothesis and the Real Interest Rate." Economics Letters, November 1981, 307-311.

________. "Small Menu Costs and Large Business Cycles." Quarterly Journal of Economics 100 (1985): 529-537.

Okun, Arthur M. Prices and Quantities: A Macroeconomic Analysis. Washington, D.C.: The Brookings Institution, 1982.

Romer, David. "The Theory of Social Custom: A Modification and Some Extensions." Quarterly Journal of Economics 99 (1984): 717-727.

Rotemberg, Julio J. "Monopolistic Price Adjustment and Aggregate Output." Review of Economic Studies 49 (1982): 517-531.

________ and Saloner, Garth. "A Supergame-Theoretic Model of Price Wars during Booms." American Economic Review 76 (1986): 390-407.

Scherer, F.M. Industrial Market Structure and Economic Performance, 2nd Edition. Chicago: Rand-McNally, 1980.

Shapiro, Carl and Stiglitz, Joseph E. "Equilibrium Unemployment as a Worker Discipline Device." American Economic Review 74 (1984): 433-444.

Solow, Robert M. "Another Possible Source of Wage Stickiness." Journal of Macroeconomics 1 (1979): 79-82.

Sparks, Roger. "A Model of Involuntary Unemployment and Wage Rigidity." Journal of Labor Economics 4 (1986): 560-581.

Stiglitz, Joseph E. "Equilibrium in Product Markets with Imperfect Information." American Economic Review 69 (May 1979): 339-345.

_______. "Price Rigidities and Market Structure." American Economic Review 69 (May 1979): 339-345.

Woglom, Geoffrey. "Underemployment Equilibrium with Rational Expectations." Quarterly Journal of Economics 97 (1982): 89-107.

TABLE I - Simple Yeoman Farmer Model

Private Cost / R

Labor supply elasticity $(1/(\gamma-1))$	Mark-up $(1/(\varepsilon-1))$ 5%	15%	50%	100%
.05	2.38 / 1.05	2.16 / 1.16	1.64 / 1.55	1.22 / 2.10
.15	.79 / 1.06	.71 / 1.19	.53 / 1.65	.39 / 2.31
.50	.23 / 1.10	.20 / 1.30	.14 / 2.04	.10 / 3.13
1.00	.11 / 1.15	.10 / 1.47	.06 / 2.67	.04 / 4.50

Note: Private Cost is for a five percent change in money. Private Cost is measured as a percentage of revenue when prices are flexible.

TABLE II - Ad Hoc Model

Private Cost / R
for various degrees of Real Rigidity

$1/(\varepsilon-1)=.15$, $1/(\gamma-1)=.15$

π	PC / R
.127*	.71 / 1.19
.050	.28 / 3.04
.025	.14 / 6.09
.010	.06 / 15.2
.005	.03 / 30.4
.002	.01 / 76.1
.001	.01 / 152.1

$1/(\varepsilon-1)=.15$, $1/(\gamma-1)=1.00$

π	PC / R
.115*	.10 / 1.47
.050	.04 / 3.37
.025	.02 / 6.75
.010	.01 / 16.9
.005	.00 / 33.7
.002	.00 / 84.3
.001	.00 / 168.6

$1/(\varepsilon-1)=1.00$, $1/(\gamma-1)=.15$

π	PC / R
.474*	.39 / 2.31
.200	.17 / 5.37
.050	.04 / 21.5
.025	.02 / 43.0
.010	.01 / 107.5
.005	.00 / 214.9
.002	.00 / 537.3

$1/(\varepsilon-1)=1.00$, $1/(\gamma-1)=1.00$

π	PC / R
.333*	.04 / 4.50
.200	.03 / 7.50
.050	.01 / 30.0
.025	.00 / 60.0
.010	.00 / 150.0
.005	.00 / 300.0
.002	.00 / 750.0

* Real Rigidity when k=0

Note: Private Cost is for a five percent change in revenue. Private Cost is measured as a percentage of revenue when prices are flexible.

TABLE III - Efficiency Wage Model

$1/(\gamma-1)=1/(\epsilon-1)=.15$

a=.50

	ϕ	π	PC	R
Wal	----	6.70	37.60	.02
EW	2.00	1.00	.84	.40
	1.50	.50	.21	1.44
	1.10	.10	.01	32.93
	1.05	.05	.00	130.19

$1/(\gamma-1)=1/(\epsilon-1)=1.00$

a=.50

	ϕ	π	PC	R
Wal	---	1.00	.13	1.50
EW	2.00	1.00	.13	1.44
	1.50	.50	.03	4.50
	1.10	.10	.00	87.50
	1.05	.05	.00	337.50

$1/(\gamma-1)=1/(\epsilon-1)=.15$

a=0

	ϕ	π	PC	R
Wal	----	6.70	37.60	.02
EW	2.00	1.00	.84	.91
	1.50	.50	.21	3.60
	1.10	.10	.01	89.15
	1.05	.05	.00	356.19

$1/(\gamma-1)=1/(\epsilon-1)=.15$

a=1.00

	ϕ	π	PC	R
Wal	---	6.70	37.60	.02
EW	2.00	1.00	.84	.26
	1.50	.50	.21	.79
	1.10	.10	.01	14.56
	1.05	.05	.00	55.60

Note: Private Cost is for a five percent change in revenue. Private Cost is measured as a percentage of revenue when prices are flexible.

FIGURE I - Imperfect Information Model

Asymmetric Effects of Price Changes