Sticky Prices As Coordination Failure

By LAURENCE BALL AND DAVID ROMER*

This paper links the "coordination failure" and "menu cost" approaches to the microeconomic foundations of Keynesian macroeconomics. If a firm's desired price is increasing in others' prices, then the gain from price adjustment after a nominal shock is greater if others adjust. This "strategic complementarity" leads to multiple equilibria in the degree of rigidity. Welfare may be much higher in the equilibria with less rigidity. Thus, nominal rigidity arises from a failure to coordinate price changes. (*JEL* E12, E30)

Keynesian macroeconomics waned in the 1970's because economists grew disenchanted with its weak microeconomic foundations. The central difficulty was that Keynesian models were based on ad hoc rigidities in nominal wages and prices. The 1980's produced two approaches to reviving Keynesian theory. The "menu cost" literature (N. Gregory Mankiw, 1985; George Akerlof and Janet Yellen, 1985) seeks to provide rigorous explanations for nominal rigidities. These papers argue that small frictions in price setting are enough to produce large nominal rigidities. In contrast, the "coordination failure" literature (Russell Cooper and Andrew John, 1988) abandons nominal rigidities and seeks alternative foundations for Keynesian models. The central idea is that many economic activities, such as production (e.g., John Bryant, 1983), trade (e.g., Peter Diamond, 1982), and investment (e.g., Nobuhiro Kiyotaki, 1988), exhibit "synergism" or "strategic complementarity": one agent's optimal level of activity depends positively on others' activity. Strategic complementarity can lead to multiple equilibria, with high-activity equilibria superior to low-activity equilibria. Thus, an economy may be stuck in an "underemployment equilibrium" even though a superior equilibrium exists.

Models with nominal rigidities and models with coordination failures are often presented as competing paradigms.[1] This paper shows that this view is incorrect. We take a step toward unifying the foundations of Keynesian economics by showing that the two sets of ideas are highly complementary. Nominal rigidity arises from a failure to coordinate price changes. This failure has the essential features of coordination failures in previous models. Flexibility in one firm's price increases the incentives for other firms to make their prices flexible. This strategic complementarity leads to multiple equilibria in the degree of nominal rigidity. Equilibria with less rigidity (more active price adjustment) are often Pareto superior to equilibria with more rigidity.

These results contribute to our understanding both of coordination failure and of nominal rigidity. The range of Keynesian phenomena explained by coordination failures is greatly expanded. Previous coordination-failure models contain only real variables and thus ascribe no role to monetary policy or other determinants of nominal spending. Our results suggest that coordination failure is at the root of inefficient nonneutralities of money. Theories of nominal rigidities gain new empirical and policy im-

*Department of Economics, Princeton University, Princeton, NJ 08544; and Department of Economics, University of California, Berkeley, CA 94720. We are grateful for helpful comments from Ben Bernanke, Stephen Cecchetti, Andrew Policano, the referees, and participants in the May 1987 conference on coordination failure at the University of Iowa. The National Science Foundation provided financial support.

[1]See, for example, Cooper and John (1988 pp. 441–2) and Diamond (1982 p. 881).

plications. As we argue below, strategic complementarity in price adjustment helps to explain variation in nominal rigidity across countries and over time. Our finding of coordination failure suggests a role for government intervention, either to improve coordination of price adjustment or to offset the effects of rigidity through active monetary policy.

We study the coordination of price adjustment in a model similar to those in Olivier Blanchard and Kiyotaki (1987) and Ball and Romer (1989a). Section I describes the model, and Section II presents our main results. In the model, imperfectly competitive firms decide whether to pay a small cost of adjusting prices after a nominal shock. Previous work shows that considerable rigidity can be an equilibrium even if it results in large, highly inefficient fluctuations in output. This paper shows that there are additional equilibria with less rigidity, and often with higher welfare. Specifically, for a range of realizations of the shock, both full adjustment of prices and complete nonadjustment are equilibria; this implies that an economy facing a distribution of shocks possesses a continuum of equilibrium degrees of rigidity. The size of the continuum is increasing in the degree of strategic complementarity in price adjustment.[2]

Section III sketches two extensions of our analysis. First, we introduce heterogeneity among price setters, so that some prices adjust to a shock and others do not. There can be multiple equilibria in the proportion that adjust and, hence, in the size of the shock's real effects. Second, we consider a simple dynamic model in which firms choose between adjusting prices every period and every two periods. Here, there are multiple equilibria in the *frequency* of adjustment and, hence, in the dynamics of the price level. In addition, this example illustrates a difference between our model and other coordination-failure models: while the economy possesses multiple short-run equilibria, it converges to a unique long-run equilibrium.

Section IV concludes by discussing the model's empirical and policy implications.

I. The Model

The model is similar to the one in Ball and Romer (1989a), which is based on Blanchard and Kiyotaki (1987). While Blanchard and Kiyotaki specify both goods and labor markets, we assume for simplicity that the economy consists of "yeoman farmers" who sell goods produced with their own labor. That is, we suppress the labor market and focus on rigidities in output prices. Subsection A describes tastes and technology, and Subsection B describes how we measure nominal rigidity.

A. *Tastes and Technology*

There is a continuum of yeoman farmers indexed by i and distributed uniformly on $[0,1]$. Each farmer produces a differentiated good, sells this product, and purchases the products of all other farmers. Farmers take each other's prices as given.

Farmer i's utility function is

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

[2]The surveys of menu-cost models by Blanchard (1987) and Julio Rotemberg (1987) contain other discussions of multiple equilibria in the degree of rigidity. Rotemberg's argument is closer to ours. Costas Azariadis and Cooper (1985) and Roger Farmer and Michael Woodford (1984) present overlapping-generations models in which both flexible and sticky prices are equilibria. These models differ from ours both in the meaning of price rigidity and in the source of multiple equilibria. In overlapping-generations models, money serves only as a store of value. Thus, a sticky price level means sticky real asset prices. In our model, money is the medium of exchange, and so sticky nominal prices mean sticky transactions prices. In Azariadis and Cooper (1985) and in Farmer and Woodford (1984), the source of multiple equilibria is the more general fact that overlapping-generations models have a large indeterminancy of equilibria (Woodford, 1984); the flexible and sticky price equilibria are just two of many. In our model, multiple equilibria arise from the combination of menu costs and strategic complementarity in price-setting, and (with the minor exception discussed in footnote 7) complete rigidity and full adjustment are the only equilibrium responses to a shock.

where

$$(2)\qquad C_i = \left[\int_{j=0}^{1} C_{ij}^{(\varepsilon-1)/\varepsilon}\,dj\right]^{\varepsilon/(\varepsilon-1)}$$

and where L_i is farmer i's labor supply; C_i is an index of farmer i's consumption; C_{ij} is farmer i's consumption of the product of farmer j; z is a small positive constant (the menu cost); D_i is a dummy variable equal to 1 if farmer i changes his nominal price; 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^{γ} in (1) is chosen for convenience. Finally, farmer i has a linear production function:

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

where Y_i is farmer i's output.

The utility function determines the demand for farmer i's product, given aggregate consumption and the farmer's relative price:

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

where P_i is the price of good i, C is aggregate consumption, P is the aggregate price index, and

$$(5)\qquad C = \int_{j=0}^{1} C_j\,dj$$

$$(6)\qquad P = \left[\int_{j=0}^{1} P_j^{1-\varepsilon}\,dj\right]^{1/(1-\varepsilon)}.$$

Farmer i's consumption equals his real revenues:

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

[See Blanchard and Kiyotaki (1987) for derivations of (4)–(7).] Substituting (3), (4), and (7) into (1) yields farmer i's utility as a function of aggregate consumption and his relative price:

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

To make nominal disturbances possible, we assume that money is required for transactions, so aggregate nominal spending equals the money stock:

$$(9)\qquad PC = M.$$

Julio Rotemberg (1987) describes a specific transactions technology that gives rise to (9). Purchases must be made with money. At the start of the model's single period, a central bank distributes an amount of money M to farmers. A dollar can be spent only once during a period (velocity equals one), and farmers must repay the bank at the end of the period. These assumptions imply (9) and assure that the budget constraint (7) is satisfied.[3]

Substituting (9) into (8) yields

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

[3]Two details of this story deserve mention. First, individuals choose how much money to receive from the bank. The bank equates the total demand for money to the supply, M, by adjusting the amount that agents are required to repay. The demand is infinite if the required repayment is less than one-for-one and zero if it is greater; thus, the equilibrium repayment is one-for-one. Second, aggregate nominal spending is $\int_{j=0}^{1} P_j Y_j\,dj$. Using (7) and (5), this can be rewritten as $\int_{j=0}^{1} PC_j\,dj = PC$. Thus, (9) follows from the assumption that aggregate spending equals M.

Obviously the ideas behind (9) are more general than Rotemberg's model. Blanchard and Kiyotaki derive (9) by putting money in the utility function. In a dynamic model, money can be introduced through a more realistic cash-in-advance constraint or through overlapping generations [although these models may not yield (9) exactly]. Our approach introduces money as simply as possible.

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

$$(11) \qquad P_i^* = P^{\phi}M^{1-\phi}$$

with

$$\phi = 1 - \frac{\gamma - 1}{\gamma\varepsilon - \varepsilon + 1} \qquad 0 < \phi < 1$$

where ϕ is the elasticity of P_i^* with respect to the aggregate price level. Equation (11) implies that, in the absence of menu costs, symmetric equilibrium occurs when $P_i = P = M$. Finally, combining (10) and (11) yields farmer i's utility as a function of real balances, the ratio of his price to the utility-maximizing level, and the menu cost:

$$(12) \quad U_i = \left(\frac{M}{P}\right)^{\gamma(1-\varepsilon+\varepsilon\phi)} \times \left[\left(\frac{P_i}{P_i^*}\right)^{(1-\varepsilon)} - \frac{\varepsilon - 1}{\gamma\varepsilon}\left(\frac{P_i}{P_i^*}\right)^{-\gamma\varepsilon}\right] - zD_i$$

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

The analysis below uses several properties of the function $V(M/P, P_i/P_i^*)$ in the vicinity of $M/P = 1$, $P_i/P_i^* = 1$, the equilibrium in the absence of menu costs. This function is increasing and concave in M/P: $V_1(M/P, P_i/P_i^*) > 0$, $V_{11}(M/P, P_i/P_i^*) < 0$ (subscripts denote partial derivatives). Intuitively, a rise in M/P benefits a farmer by raising aggregate consumption and thus shifting out the demand curve that he faces. Concavity means that farmers dislike fluctuations in demand. The source of this risk aversion is the increasing marginal disutility of producing output: $\gamma > 1$ in (1). Finally, since $P_i/P_i^* = 1$ maximizes utility by definition,[4]

$$V_2\left(\frac{M}{P}, 1\right) = 0$$

$$V_{22}\left(\frac{M}{P}, 1\right) < 0 \quad \forall \quad \frac{M}{P}.$$

B. *Nominal Rigidity*

Here, we describe the basic experiment that we consider. The economy begins with $M = 1$ and $P_i = P_i^* = 1 \ \forall \ i$. One can think of this as the situation in an earlier period when the economy is at its long-run equilibrium. In the current period, a shock occurs: M changes to $1 + x$. Each farmer chooses between keeping his price at 1 or paying the menu cost and changing his price to the new P_i^*. We determine the circumstances under which adjustment and nonadjustment of prices are equilibria.

While natural, the assumption that prices initially equal 1 is ad hoc (the "earlier period" is not explicit). Therefore, in an Appendix we follow our earlier article (Ball and Romer, 1989a) in assuming that farmers choose initial prices optimally, given a distribution of shocks with mean 0. Farmers choose initial prices different from 1 (i.e., certainty equivalence fails), because utility is not quadratic. We find that the results in the text are altered only slightly.[5]

Our formulation assumes that farmers set prices in nominal terms and thus that they can eliminate the real effects of money only by adjusting their prices after observing M. A natural question is why farmers do not simply set indexed prices (i.e., announce a function relating their prices to M) and

[4]As this discussion suggests, our use of specific functional forms is not important for our main results. Aside from the properties of $V(\cdot)$ described here, the only essential assumption is strategic complementarity in utility-maximizing prices: P_i^* must be increasing in P.

[5]The less rigorous approach in the text is in a sense more realistic, since actual price rigidity is usually a failure to adjust from a previous price. This idea is captured rigorously in the dynamic model of Section III.

thereby eliminate the need for *ex post* adjustment.[6] The answer is that indexing a price, like adjusting *ex post*, requires small amounts of effort. In this case, the "menu costs" include the costs of computing the number of dollars corresponding to indexed prices and of learning to think in real rather than nominal terms. As Bennett McCallum (1986) explains, it is easier to set prices in nominal terms—in units of money—because money is the medium of exchange. In other words, it is convenient to use the medium of exchange as the unit of account.

By assuming that if farmers achieve flexibility they do so through *ex post* adjustment, we are implicitly assuming that *ex post* adjustment is less expensive than indexation. Assuming the reverse does not change the basic character of our results. In this case, farmers choose between indexed prices and noncontingent prices before observing the monetary shock. They base their decision on the variance of the shock, which determines the expected cost of forgoing indexation. Just as our basic model produces multiple equilibria for a range of realizations of the shock, the alternative model produces multiple equilibria (indexation and nonindexation) for a range of variances.

II. Coordination Failure

This section presents our central results. Subsection A shows that both full adjustment of prices and complete nonadjustment are Nash equilibria for a range of sizes of the monetary shock. It follows that the economy possesses a continuum of equilibrium degrees of nominal rigidity. Subsection B compares welfare in the different equilibria.

A. *Multiple Equilibria*

We first determine when nonadjustment of all prices is an equilibrium. This is how previous menu-cost papers measure nominal rigidity. The condition for nonadjustment to be an equilibrium is that a representative farmer i chooses not to pay the menu cost if no other farmer pays. If farmer i maintains a rigid price along with the others, then $D_i = 0$. $P_i = P = 1$, which implies $M/P = M$, and using (11), $P_i/P_i^* = 1/M^{1-\phi}$. Thus, the farmer's utility is $V(M, 1/M^{1-\phi})$.

If farmer i pays the menu cost despite others' nonadjustment, then $D_i = 1$. Adjustment of one price does not affect the aggregate price level, so $P = 1$ and $M/P = M$. Adjustment allows farmer i to set $P_i = P_i^*$, so $P_i/P_i^* = 1$. Thus, farmer i's utility is $V(M, 1) - z$.

These results imply that the representative farmer chooses not to pay the menu cost—and thus that rigidity is an equilibrium—if

$$(13)\quad G_N < z$$
$$G_N \equiv V(M,1) - V\left(M, \frac{1}{M^{1-\phi}}\right).$$

G_N is the gain to a farmer from adjusting, given that others do not adjust. Rigidity is an equilibrium if G_N is less than the menu cost.

Taking a second-order approximation of G_N around $M = 1$ yields

$$(14)\quad G_N \cong \left[V(1,1) + V_1 x + \tfrac{1}{2}V_{11}x^2\right] - \left[V(1,1) + V_1 x + \tfrac{1}{2}V_{11}x^2 + \tfrac{1}{2}V_{22}(1-\phi)^2 x^2\right] = \frac{-(1-\phi)^2}{2}V_{22}x^2$$

where $x \equiv M - 1$ and where subscripts of V denote partial derivatives evaluated at $(1,1)$ (recall that V_{22} is negative). The derivation uses the fact that $V_2(M/P, 1) = 0 \;\forall\; M/P$, which implies $V_2(1,1) = V_{12}(1,1) = 0$. Equation (14) shows that the gain from adjusting is increasing in the size of the shock. Equations (13) and (14) imply that the gain is less

[6] In this model, indexation of individual prices to the aggregate price level would not accomplish the same thing. If each farmer set $P_i = P$, relative prices would be constant, but the aggregate price level (and hence real output) would be indeterminate.

than the menu cost, and so rigidity is an equilibrium, if $|x| < x_N$, where

$$(15) \qquad x_N = \sqrt{\frac{-2z}{(1-\phi)^2 V_{22}}}.$$

We now ask when price *flexibility* is an equilibrium. This occurs when farmer i chooses to pay the menu cost if all others pay. If all other farmers pay the menu cost, then $P = M$, so $M/P = 1$. If farmer i pays as well, then $D_i = 1$ and $P_i/P_i^* = 1$; thus, his utility is $V(1,1) - z$. If farmer i does not pay the menu cost even though others do, then $D_i = 0$, $P_i = 1$, and, using (11), $P_i/P_i^* = 1/M$. In this case, farmer i's utility is $V(1,1/M)$.

These results show that farmer i pays the menu cost if

$$(16) \qquad G_A > z$$

$$G_A \equiv V(1,1) - V\left(1, \frac{1}{M}\right).$$

Flexibility is an equilibrium if G_A, the gain from adjusting given that others adjust as well, is greater than the menu cost. A second-order approximation yields

$$(17) \qquad G_A = -\tfrac{1}{2} V_{22} x^2.$$

Like G_N, G_A is increasing in the size of the shock. Equations (16) and (17) imply that flexibility is an equilibrium if $|x| > x_A$, where

$$(18) \qquad x_A = \sqrt{\frac{-2z}{V_{22}}}.$$

Combining (15) and (18) yields our central result:

$$(19) \qquad \frac{x_N}{x_A} = \frac{1}{1-\phi}$$

in which ϕ, the elasticity of P_i^* with respect to P, is between 0 and 1. Thus, $x_A < x_N$. If $|x|$ is between x_A and x_N, then both rigidity and flexibility are equilibria.[7,8]

These results can be summarized as follows. For small monetary shocks ($|x| < x_A$), each farmer refuses to pay the menu cost regardless of others' decisions, and so rigidity is the only equilibrium. For large shocks ($|x| > x_N$), each farmer pays regardless of others, and so flexibility is the only equilibrium. However, for shocks of intermediate size ($x_A < |x| < x_N$), a farmer pays if and only if others do. The reason is that a farmer's gain from adjusting his price is greater if others adjust: G_A is greater than G_N. In Cooper and John's (1988) terminology, there is "strategic complementarity" in price adjustment. To see why, consider a positive shock for concreteness and recall that a farmer's utility-maximizing price, P_i^*, equals $P^{\phi}M^{1-\phi}$. If others keep their prices fixed at 1, P_i^* rises to $M^{1-\phi}$. However, if others adjust, P rises to M and P_i^* rises to $M > M^{1-\phi}$. That is, if others adjust, they change their prices in the same direction as the money supply, which pushes P_i^* farther from 1. Since the desired increase in P_i is larger, the incentive to adjust is larger.[9]

[7]One can show that, when both rigidity and flexibility are equilibria, there is a third equilibrium in which some farmers adjust and others do not and in which each farmer is indifferent about whether to adjust. This equilibrium is unstable: if slightly more than the required proportion of farmers adjust, then all farmers wish to adjust; if slightly fewer adjust, then none wishes to adjust.

[8]Our result that the model possesses multiple equilibria for some values of x does not appear to depend on our use of Taylor approximations. As explained below, the crucial condition for multiple equilibria is $G_A > G_N$. Without approximating, we are not able to show analytically that this holds for all parameter values, but extensive numerical calculations suggest that it does.

[9]Accommodating monetary policy would be another source of multiple equilibria. Suppose the money-supply rule is changed from $M = 1 + x$ to $M = 1 + c(P-1) + x$, $0 < c < 1$. Since $P = 1$ if prices are rigid, x_N is not affected; but if prices are flexible, the equilibrium level of P and M is $1 + [x/(1-c)]$ rather than $1 + x$. As a result, $x_A = \{[-2z(1-c)^2]/V_{22}\}^{1/2}$ and $x_N/x_A = 1/[(1-\phi)(1-c)]$. Thus, accommodating monetary policy increases the range of multiple equilibria and makes multiple equilibria possible even if $\phi \le 0$. Intuitively, accommodating policy creates an ad-

As this discussion suggests, strategic complementarity in price adjustment is tied to a simpler kind of strategic complementarity: the positive dependence of a farmer's utility-maximizing price in the absence of menu costs on the prices of others. The degree to which G_{A} exceeds G_{N} depends on ϕ, the elasticity of P_i^* with respect to P [see (14) and (17)].[10] This implies that $x_{\mathrm{N}}/x_{\mathrm{A}}$ is also increasing in ϕ [see (19)]. With strong strategic complementarity—ϕ close to 1—the range of multiple equilibria can be very large. Intuitively, changes in others' prices have a large effect on farmer i's adjustment decision when they have a large effect on the farmer's desired price.[11]

So far, our results concern equilibrium responses to a single shock. Now suppose that farmers face a distribution of shocks and choose rules for when to pay the menu cost. We restrict attention to equilibria in which all farmers pay the menu cost if $|x|$ is greater than a cutoff, x^*, that is, if the money supply lies outside of $(1-x^*, 1+x^*)$. The cutoff x^* is a natural measure of the degree of rigidity. Our results imply that any value of x^* between x_{A} and x_{N} is an equilibrium; a farmer will adopt any value in this range as a cutoff if all others do. Thus, there is a continuum of equilibrium degrees of nominal rigidity.[12]

Finally, we note an unrealistic feature of our model: since complete adjustment of prices is a unique equilibrium when $|x| > x_{\mathrm{N}}$, very large nominal shocks are necessarily neutral. In practice, large shocks appear to have large real effects; for example, sharp monetary contractions appear to cause deep recessions. Our result is an artifact of the simple static specification. As explained below, it disappears in dynamic versions of the model.

B. *Welfare*

Many coordination-failure models possess multiple equilibria that can be Pareto ranked. In particular, high-"effort" equilibria (for example, those with high levels of production) are often superior to low-effort equilibria. It is natural to ask whether this is the case in the current model. When there are multiple equilibria in the degree of price rigidity, is less rigidity (more effort expended on price adjustment) better?

To study welfare, we again assume that farmers face a distribution for the monetary shock, x, and pay the menu cost if $|x|$ exceeds a cutoff, x^*. For a symmetric distribution with mean zero, we derive the socially optimal value of x^*: the one that maximizes farmers' expected utility. To determine the welfare properties of equilibrium rigidity, we compare the optimal x^* to x_{A} and x_{N}, the endpoints of the range of equilibria. We continue to assume that farmers initially set their prices to 1, the equilibrium value in the absence of shocks; in the Appendix, we study the case in which

ditional source of strategic complementarity: when others raise their prices, M rises, which raises P_i^*.

[10] While the result that a farmer's utility-maximizing price increases with others' prices is clearly realistic, one can find cases in which it does not hold. For example, ϕ can be negative (prices can be strategic substitutes) if aggregate demand increases more than one-for-one with real money (as in Ball [1987]). If ϕ is negative, there is always a unique equilibrium in the fraction of farmers who adjust their prices.

[11] In terms of the model, ϕ approaches 1 as γ approaches 1 (constant marginal utility of leisure) and as ε approaches infinity (a perfectly competitive product market). When γ approaches 1, if others do not change their prices, farmer i has no desire to change his: G_{N} approaches 0 and x_{N} approaches infinity. However, if others adjust, the benefits of adjusting with them are positive, and so the farmer adjusts if the shock is large enough: x_{A} approaches $\sqrt{2z/(\varepsilon-1)}$. Thus, there are two equilibria for any

$$|x| > \sqrt{2z/(\varepsilon-1)}\,.$$

On the other hand, if ε approaches infinity, then G_{N} approaches infinity and x_{N} approaches 0 ($x_{\mathrm{N}}/x_{\mathrm{A}}$ still approaches infinity, because x_{A} approaches 0 more quickly than does x_{N}). When markets are competitive, a farmer's desired price change is small if others' prices are rigid, but the cost of forgoing even a small change is large. Formally, G_{N} approaches infinity because V_{22} grows more quickly than $(1-\phi)^2$ shrinks [see (14)].

[12] The economy also possesses equilibria with less natural rules for when to change prices. For example, the set of realizations of M for which prices are rigid can be an asymmetric range, $(1-x_1^*, 1+x_2^*)$, or even a disconnected set, $\{(M_1^*, M_2^*), (M_3^*, M_4^*)\}$.

initial prices are chosen optimally given the distribution of shocks.[13]

Recall that a farmer's utility is $V(1,1)-z$ if all farmers pay the menu cost and $V(M,1/M^{1-\phi})$ if none pays. Thus, since all pay if $|x|>x^*$, expected utility is

$$(20)\quad E[U_i] = \{1-[F(1+x^*)-F(1-x^*)]\} \times [V(1,1)-z] + \int_{M=1-x^*}^{1+x^*} V\left(M,\frac{1}{M^{1-\phi}}\right) f(M)\,dM$$

where $F(\cdot)$ is the cumulative distribution function for M and $f(\cdot)$ is the density function. The first-order condition for the socially optimal x^*, denoted x_S, is

$$(21)\quad -2[V(1,1)-z] + V\left(1+x_S,\frac{1}{(1+x_S)^{1-\phi}}\right) + V\left(1-x_S,\frac{1}{(1-x_S)^{1-\phi}}\right)=0$$

where we use the fact that $f(1+x)=f(1-x)$ by our assumption that $f(\cdot)$ is symmetric around 1. A second-order approximation leads to

$$(22)\quad x_S=\sqrt{\frac{-2z}{V_{11}+(1-\phi)^2V_{22}}}.$$

Our central welfare result follows from substituting the appropriate derivatives of $V(\cdot)$ into (22) and the expressions for x_N and x_A:

$$(23)\quad x_A<x_S<x_N.$$

Since $x_S<x_N$, there is a range of equilibrium values of x^* ($x_S<x^*<x_N$) with too much rigidity; in these equilibria, all farmers would be better off if the cutoff were lowered. Since $x_S>x_A$, there is a range of equilibria with too much flexibility. Finally, the social optimum ($x^*=x_S$) is always an equilibrium.

The reason that too much rigidity is possible is similar to the reason in Ball and Romer (1989a). Suppose that all farmers start with an arbitrary x^*. If one farmer lowers his cutoff while the others do not, the only benefit is that he sets $P_i=P_i^*$ more frequently; but if *all* farmers reduce x^*, there is an additional benefit. All prices adjust more frequently, and so the aggregate price level becomes more flexible. This reduces fluctuations in the real money stock and thus stabilizes the demand curves that farmers face. As explained above, farmers prefer stable demand because the disutility of labor is convex. Since the incentive for an individual to reduce x^* is smaller than the gain if all do, values of x^* above x_S can be equilibria.

Values of x^* *below* x_S can be equilibria (i.e., there can be too much flexibility) because a farmer's gain from *raising* x^* is also smaller if he does so by himself than if all do. If the others do not join the farmer in raising x^*, then for some shocks he does not adjust his price but others do. Others' adjustment increases movements in P_i^*, which raises the farmer's loss from nonadjustment. (Others' adjustment still benefits the farmer by stabilizing demand, but this effect is smaller.)

While both excessive rigidity and excessive flexibility are possible, the magnitudes of the losses are very different. Neglecting the menu cost, full flexibility is optimal ($x_S=0$ when $z=0$). Thus, the net loss from too much flexibility is bounded by the menu cost, which realistically is small. In contrast, Ball and Romer (1989a) show that the loss from too much rigidity can be arbitrarily

[13]We study average welfare given a distribution of shocks because the welfare effect of rigidity after an individual shock depends on the sign of the shock (Mankiw, 1985; Ball and Romer, 1989a). Nonadjustment to a fall in the money supply reduces output and welfare. However, nonadjustment to a positive shock increases output. This raises welfare because, under imperfect competition, the no-shock level of output is too low.

large. Intuitively, the private incentive to reduce x^*—the gain from keeping P_i closer to P_i^*—can be very small because a farmer's utility is insensitive to his relative price over a significant range. Thus, a small menu cost can produce a large x^* even if the resulting fluctuations in real output are highly inefficient. While excessive price flexibility is not likely to be an important problem, excessive rigidity may be.

III. Extensions

A. *Heterogeneous Agents*

In our basic model, multiple equilibria arise when each farmer chooses to adjust his price if and only if others do. The desire to make the same decision as others is crucial. A natural question is whether multiple equilibria are possible if heterogeneity leads some agents to adjust while others do not. Here we show that models with heterogeneity can possess multiple equilibria in the proportion of prices that adjust and, therefore, in the size of the real effects of a nominal shock. We focus on heterogeneity in the size of menu costs, which is the simplest case. Strategic complementarity is necessary for multiple equilibria; the sufficient condition depends on the distribution of the menu cost. Other sources of heterogeneity lead to similar results.

Assume that the menu cost, z, varies across farmers with cumulative distribution function $H(z)$. After a shock, farmers with z below some critical level adjust their prices, and the others do not. Let k be the proportion that adjust. We derive an equilibrium condition for k.

Let $P_A(x,k)$ be the price set by those who adjust and let $P(x,k)$ be the aggregate price level. Note that $P_A = P_i^* = P^{\phi}(1+x)^{1-\phi}$ and [approximating (6)] $P \cong kP_A + (1-k)$. These relations imply

$$(24) \qquad P_A(x,k) \cong 1 + \frac{1-\phi}{1-\phi k}x.$$

By reasoning similar to that in Section II, the gain from adjusting is

$$(25) \quad G(x,k) = V\left(\frac{1+x}{P(x,k)}, 1\right) - V\left(\frac{1+x}{P(x,k)}, \frac{1}{P(x,k)^{\phi}(1+x)^{1-\phi}}\right).$$

Using (24) and (25), one can show that

$$(26) \quad G(x,k) \cong -\frac{1}{2}\left(\frac{1-\phi}{1-\phi k}\right)^2 V_{22}x^2.$$

The crucial result is

$$(27) \qquad \frac{\partial G(x,k)}{\partial k} > 0.$$

The gain from adjusting is increasing in the proportion of firms that adjust. This is a generalization of the earlier result that the gains are greater when all adjust than when none adjusts. Again, adjustment by others moves the price level in the same direction as the money supply, which increases the deviation of P_i^* from 1.

A farmer pays his menu cost if it is less than $G(x,k)$. Thus, the proportion who pay is $H(G(x,k))$, and an equilibrium k is one that satisfies $k = H(G(x,k))$. A necessary condition for multiple equilibria is $\partial H(G(x,k))/\partial k > 0$ over some range. Since $\partial H(G(x,k))/\partial k = dH/dG \cdot \partial G/\partial k$ and $H(\cdot)$ is increasing over some range, the condition reduces to (27), which holds because of strategic complementarity. The sufficient condition depends on the size of x and the shape of $H(\cdot)$; it is easy to find examples both of multiple equilibria and of unique equilibria.[14]

[14] Introducing heterogeneous real shocks leads to similar results. Suppose that the production function (3) is replaced by $Y_i = \theta_i L_i$, that θ_i varies across farmers, and that a shock to θ_i occurs at the same time as the monetary shock. Farmer i will choose to pay the menu cost if θ_i is above an upper cutoff or below a lower cutoff; both critical values depend on x and k. Again, one can show that multiple equilibria are possible and that strategic complementarity is a necessary condition.

Our results again parallel others in the coordination-failure literature. Diamond (1982), for example, introduces heterogeneity in the costs of production opportunities. Greater aggregate production raises an agent's incentive to produce by creating more trading partners. This strategic complementarity can produce multiple equilibria in the proportion of opportunities undertaken. As in our model, sufficient conditions depend on the distribution of costs.

B. *Dynamics*

So far we have studied a static model. In reality, price rigidity is a failure of prices to adjust quickly over time. Therefore, we now consider a dynamic version of our model. We focus on an example in which farmers choose between adjusting prices every period and adjusting every two periods; at the end, we briefly consider more general cases. There are two results. First, strategic complementarity in optimal prices produces multiple equilibria in the frequency of adjustment and hence in the dynamics of real output. Second, in contrast to other coordination-failure models, the economy converges to a unique long-run equilibrium.

Assume that the money stock follows a random walk; its innovations have mean zero and variance σ_m^2. A farmer can adjust his price every period or every two periods, and he pays a menu cost z for each adjustment. When a farmer adjusts, he does so after observing the current money stock. If he adjusts every period, he always sets $P_i = P_i^*$. If farmers adjust every two periods, they all adjust in even periods; that is, price-setting is synchronized (Gary Fethke and Andrew Policano [1984] and Ball and Romer [1989b] show that this is the equilibrium timing when all shocks are aggregate). In this case, since M is a random walk, in even periods farmers set $P_t = P_t^* = M$; in odd periods, prices do not adjust to the most recent change in M.[15,16]

We assume that each farmer chooses his frequency of adjustment taking others' frequency as given and solve for Nash equilibria. This exercise is a simple extension of the static case. A farmer compares the added cost of adjusting in odd periods to the expected gain from keeping $P_i = P_t^*$ in odd periods, which depends on others' frequency of adjustment. One can show that adjustment only in even periods is an equilibrium if

$$\frac{-(1-\phi)^2}{2}V_{22}\sigma_m^2 < z \tag{28}$$

and adjustment every period is an equilibrium if

$$-\tfrac{1}{2}V_{22}\sigma_m^2 > z \tag{29}$$

where we use approximations analogous to (14) and (17). Conditions (28) and (29) are the same as the conditions for nonadjustment and adjustment in the static model except that x^2, the square of a given shock, is replaced by σ_m^2, the *expected* square of the shock. The reason is that farmers decide how frequently to adjust before observing the realizations of shocks.

Since $0 < \phi < 1$, there are multiple equilibria in price adjustment for a range of z (or, for given z, for a range of σ_m^2). This multiplicity implies multiple equilibria in output dynamics. If prices adjust every period, monetary shocks are neutral, and output is constant. If prices adjust only in even periods, shocks in odd periods cause output movements that last until the next adjustment. In contrast to our static model, the

[15] When prices are set for two periods, a farmer's optimal price in fact differs slightly from the first-period value of M, because this is not the optimal rigid price for the second period: as in the static model, certainty equivalence fails. Allowing farmers to choose prices different from the initial M introduces complications similar to the ones for the static model (see the Appendix).

[16] Rather than adjust every period, a farmer could guarantee $P_t = P_t^*$ by adjusting every two periods (or never) but indexing his price to the money stock. Thus, an alternative interpretation of the model is that a farmer chooses between setting a noncontingent price for two periods and setting an indexed price. Under this interpretation, z is an indexation cost.

output effect of an odd-period shock is strictly increasing in the size of the shock.[17]

Strategic complementarity is again the source of multiple equilibria. Intuitively, more frequent adjustment by others makes the price level respond more quickly to shocks and thus makes it more volatile. For $\phi > 0$, greater volatility in the price level implies greater volatility in a farmer's desired price, which increases his incentive to adjust frequently. For some parameter values, the incentive to adjust every period exceeds the added cost if and only if others adjust every period.

While we focus here on a simple example, the central results carry over to more general settings. An earlier version of this paper (Ball and Romer, 1988) considers a continuous-time model in which farmers can choose any frequency of adjustment. Strategic complementarity in desired prices can lead to multiple equilibria in the frequency. This implies multiple equilibria in the adjustment speed of the aggregate price level and hence in the path of output following a shock. Sufficient conditions for multiple equilibria depend on how steeply the costs of price adjustment increase with the frequency of adjustment.

Finally, our dynamic model makes clear a difference between coordination failure in price adjustment and coordination failures identified by previous authors. In previous models, there is no reason for an economy in a Pareto-dominated equilibrium to leave it. For example, if each agent in the Diamond model does not produce because others do not produce, this situation need not improve over time. In contrast, our model implies differences between the short-run and long-run behavior of the economy. Multiple equilibria in the frequency of price adjustment imply multiple equilibria in the size and duration of the output effects of nominal shocks. However, there is a unique long-run response to a shock: prices eventually adjust fully, and the shock is neutral.[18]

IV. Conclusions and Implications

This paper shows that nominal price rigidity can arise from a failure of firms to coordinate price changes. Increases in price flexibility by different firms are strategic complements: greater flexibility of one firm's price raises the incentives for other firms to make their prices more flexible. Strategic complementarity can lead to multiple equilibria in the degree of nominal rigidity, and welfare may be much higher in the low-rigidity equilibria. Thus, the inefficient economic fluctuations resulting from nominal shocks might be greatly reduced if agents could "agree" to move to a superior equilibrium.

We conclude by discussing the empirical and policy implications of our results. One implication is that there can be considerable variation across economies in the degree of nominal rigidity and hence in the size of real fluctuations, without large variation in the underlying determinants of rigidity. Multiple equilibria imply that differences in rigidity can arise without any underlying differences. Even with unique equilibria, strategic complementarity implies that there is a "multiplier" (Cooper and John, 1988): small underlying differences can lead to large differences in rigidity. Nominal rigidity does in fact appear to vary considerably across countries; for example, Dennis Grubb et al. (1983) estimate that the adjustment of nominal wages to inflation is more than three times as fast in the average Western European country as in the United States. It could be a mistake to search for explanations of such differences based on the un-

[17] The result that money matters in odd but not even periods is unattractive, but it can be eliminated through realistic modifications of the model. For example, if idiosyncratic productivity or demand shocks arrive at different times for different farmers, then there can be an equilibrium with staggered adjustment: half of all prices change every period (Ball and Romer, 1989b). In this case, the effect of a shock does not depend on when it occurs, and the shock's real effects are strictly increasing in its size.

[18] If we modified the model so that the short-run response of the economy had permanent effects, through either capital accumulation or more exotic "hysteresis" mechanisms (Blanchard and Lawrence Summers, 1986), then the economy would no longer have a unique long-run equilibrium. Even in this case, however, there would be a unique long-run degree of price rigidity (full flexibility).

derlying natures of economies. Perhaps the apparent importance of unexplained "institutions" simply reflects the fact that different economies settle at different equilibria.

Another set of empirical implications arises if we ask why an economy arrives at one equilibrium rather than another. Current coordination-failure models generally do not address this subject, but a natural possibility is that the selection of an equilibrium is determined by history (Howard Naish, 1987; Lawrence Summers, 1987). For concreteness, consider the institutions governing wage-setting, such as the presence or absence of indexation. It appears natural to assume that these arrangements do not change with changing economic conditions as long as existing institutions continue to be among the set of equilibria. With this additional assumption, our model suggests that differences in wage-setting across similar economies can be explained by differences in past conditions; differences in past inflation variability, for example, might account for differences in the prevalence of indexation. It does not appear difficult to test for such an effect of history. One might, for example, regress a cross-country measure of the extent of indexation on current and historical variables.

Our results also add to the implications of menu-cost models for microeconomic data. One can test directly for strategic complementarity with data on the lengths of labor contracts or the frequency of changes in individual prices. The natural approach is to estimate the relation across countries or time periods between the frequency of an individual firm's wage or price adjustment and the average frequency in the economy. (Of course, there is an identification problem, since one firm's frequency could respond to the same unobservable variables as others' frequency; one would need to find instruments.) Such a test would be in the spirit of Aloysius Siow (1987), who uses microeconomic data to test for strategic complementarity in individuals' hours of work.

The result in previous papers that equilibrium rigidity can be excessive suggests a role for government regulation of price-setting, such as restrictions on the lengths of labor contracts. This paper's results strengthen this policy implication in several ways. First, with multiple equilibria, policy can be less coercive. Instead of prohibiting certain contract provisions, the government could simply convene meetings of business and labor leaders to coordinate adjustment (as some European governments appear to do). Second, by moving the economy to a new equilibrium, temporary regulations can permanently change the degree of nominal rigidity. There is evidence of such effects: Stephen Cecchetti (1987) finds that the Nixon wage–price controls have permanently altered the provisions of U.S. labor contracts. Third, the multiplier arising from strategic complementarity magnifies the effects of policy. Regulation of union contracts would directly affect only a small fraction of wages in the United States. However, more flexible union wages would increase the incentives for wage and price flexibility throughout the economy and thus could have large effects on overall flexibility.

Finally, if coordination of wage and price adjustment proves difficult, an alternative is to substitute active monetary policy. In the *General Theory*, John Maynard Keynes (1936 pp. 266–8) argued that it is easier for the government to offset a fall in demand by increasing the money stock than for decentralized agents to reduce nominal wages in tandem. As Summers (1987) points out, governments adjust schedules through daylight saving time because it is difficult for decentralized agents to coordinate on a desirable equilibrium. Perhaps governments should be responsible for offsetting macroeconomic shocks for similar reasons.

Appendix

This appendix relaxes the assumption of our static model that all prices equal 1 before the monetary shock occurs. We assume instead that farmers choose initial prices optimally and show how this affects our results. The analysis draws heavily on Ball and Romer (1989a). As in that paper, we assume that the distribution of the monetary shock is symmetric around zero, single-peaked, and continuous.

The price that a farmer sets before observing the money supply depends on others' initial prices and on the value of the cutoff x^*. In symmetric equilibrium, each farmer's initial price is

$$P_0(x^*) \cong 1 + \frac{\gamma}{2}\hat{\sigma}_M^2(x^*) \tag{A1}$$

where $\hat{\sigma}_M^2(x^*)$ is the variance of M conditional on $1 - x^* < M < 1 + x^*$ (see Ball and Romer, 1989a). Given our use of second-order approximations, assuming initial prices equal to P_0 rather than 1 does not affect our results about equilibrium rigidity: the expressions for x_N and x_A in the text remain valid (Ball and Romer [1989a] shows this for x_N). We now show, however, that the socially optimal degree of rigidity changes slightly.

If initial prices are P_0 and prices are rigid, then $M/P = M/P_0$ and $P_i/P_i^* = P_0^{1-\phi}/M^{1-\phi}$. Thus, when initial prices are set optimally, a farmer's expected utility, (20), becomes

$$E[U_i] = \{1 - [F(1+x^*) - F(1-x^*)]\}[V(1,1) - z] + \int_{m=1-x^*}^{1+x^*} V\left(\frac{M}{P_0(x^*)}, \frac{[P_0(x^*)]^{1-\phi}}{M^{1-\phi}}\right) f(M)\,dM. \tag{A2}$$

The first-order condition for x_S is

$$\begin{aligned} &-[f(1-x_S) + f(1+x_S)][V(1,1) - z] \\ &+ f(1-x_S)V\left(\frac{1-x_S}{P_0(x_S)}, \frac{[P_0(x_S)]^{1-\phi}}{(1-x_S)^{1-\phi}}\right) \\ &+ f(1+x_S)V\left(\frac{1+x_S}{P_0(x_S)}, \frac{[P_0(x_S)]^{1-\phi}}{(1+x_S)^{1-\phi}}\right) \\ &+ \left\{\int_{M=1-x_S}^{1+x_S}\left[V_1\left(\frac{M}{P_0(x_S)}, \frac{[P_0(x_S)]^{1-\phi}}{M^{1-\phi}}\right)\times\left(\frac{-M}{[P_0(x_S)]^2}\right)\right.\right. \\ &\left.\left. + V_2\left(\frac{M}{P_0(x_S)}, \frac{[P_0(x_S)]^{1-\phi}}{M^{1-\phi}}\right)\times\left(\frac{(1-\phi)[P_0(x_S)]^{-\phi}}{M^{1-\phi}}\right)\right] f(M)\,dM\right\} \\ &\times P_0'(x_S) = 0 \end{aligned} \tag{A3}$$

where $P_0' \equiv (\partial P_0/\partial x^*)$. Taking a second-order approximation and substituting (A1) for P_0 yields

$$\begin{aligned} &-[f(1-x_S) + f(1+x_S)] \\ &\times[V(1,1) - z] + f(1-x_S) \\ &\times\{V(1,1) + V_1[-x_S - (\gamma/2)\hat{\sigma}_M^2] \\ &+ (1/2)V_{11}x_S^2 + (1/2)V_{22}(1-\phi)^2x_S^2\} \\ &+ f(1+x_S)\{V(1,1) + V_1[x_S - (\gamma/2)\hat{\sigma}_M^2] \\ &+ (1/2)V_{11}x_S^2 \\ &+ (1/2)V_{22}(1-\phi)^2x_S^2\} \\ &-(\gamma/2)V_1[f(1+x_S) + f(1-x_S)] \\ &\times(x_S^2 - \hat{\sigma}_M^2) = 0. \end{aligned} \tag{A4}$$

Finally, using the fact that $f(1+x) = f(1-x)$, the solution for x_S is

$$x_S \cong \sqrt{\frac{-2z}{V_{11} + (1-\phi)^2V_{22} - \gamma V_1}}. \tag{A5}$$

Substituting the derivatives of $V(\cdot)$ into (A5) establishes that $x_S < x_N$ and that x_S can be either greater or less than x_A. The possibility of $x_S < x_A$, which implies that *all* equilibria possess too much rigidity, is the main departure of these results from the ones in the text. The explanation is that P_0, the price level under rigidity, is greater than 1, its level in the text. Thus, average output under rigidity is lower than in the text, which makes it more likely that reducing rigidity would increase welfare.

REFERENCES

Akerlof, George and Yellen, Janet, "A Near-Rational Model of the Business Cycle, with Wage and Price Inertia," *Quarterly*

Journal of Economics, Supplement 1985, *100* (5), 823–38.

Azariadis, Costas and Cooper, Russell, "Nominal Wage Rigidity as a Rational Expectations Equilibrium," *American Economic Review*, May 1985 (*Papers and Proceedings*), *75*, 31–5.

Ball, Laurence, "Externalities from Contract Length," *American Economic Review*, September 1987, *77*, 615–29.

______ **and Romer, David,** "Sticky Prices As Coordination Failure," mimeo, Princeton University, 1988.

______ **and** ______, (1989a) "Are Prices Too Sticky?" *Quarterly Journal of Economics*, August 1989, *104*, 507–24.

______ **and** ______, (1989b) "The Equilibrium and Optimal Timing of Price Changes," *Review of Economic Studies*, April 1989, *56*, 179–98.

Blanchard, Olivier, "Why Does Money Affect Output? A Survey," NBER (Cambridge, MA) Working Paper No. 2285, June 1987; *Handbook of Monetary Economics*, forthcoming.

______ **and Kiyotaki, Nobuhiro,** "Monopolistic Competition and the Effects of Aggregate Demand," *American Economic Review*, September 1987, *77*, 647–66.

______ **and Summers, Lawrence,** "Hysteresis and the European Unemployment Problem," in Stanley Fischer, ed., *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press, 1986, pp. 15–77.

Bryant, John, "A Simple Rational Expectations Keynes-Type Model," *Quarterly Journal of Economics*, August 1983, *98*, 525–9.

Cecchetti, Stephen, "Indexation and Incomes Policy: A Study of Wage Adjustment in Unionized Manufacturing," *Journal of Labor Economics*, July 1987, *5*, 391–412.

Cooper, Russell and John, Andrew, "Coordinating Coordination Failures in Keynesian Models," *Quarterly Journal of Economics*, August 1988, *103*, 441–63.

Diamond, Peter, "Aggregate Demand Management in Search Equilibrium," *Journal of Political Economy*, October 1982, *90*, 881–94.

Farmer, Roger E. A. and Woodford, Michael, "Self-Fulfilling Prophecies and the Business Cycle," CARESS Working Paper No. 84-12, University of Pennsylvania, April 1984.

Fethke, Gary and Policano, Andrew, "Wage Contingencies, the Pattern of Negotiation, and Aggregate Implications of Alternative Contract Structures," *Journal of Monetary Economics*, September 1984, *14*, 151–71.

Grubb, Dennis, Jackman, Richard and Layard, Richard, "Wage Rigidity and Unemployment in OECD Countries," *European Economic Review*, March/April 1983, *21*, 11–39.

Keynes, John Maynard, *The General Theory of Employment, Interest, and Money*, London: Macmillan, 1936.

Kiyotaki, Nobuhiro, "Multiple Expectational Equilibria under Monopolistic Competition," *Quarterly Journal of Economics*, November 1988, *103*, 695–713.

Mankiw, N. Gregory, "Small Menu Costs and Large Business Cycles," *Quarterly Journal of Economics*, May 1985, *100*, 529–37.

McCallum, Bennett, "On 'Real' and 'Sticky-Price' Theories of the Business Cycle," *Journal of Money, Credit, and Banking*, November 1986, *18*, 397–414.

Naish, Howard, "The Costs of Rational Pricing Behavior, and the Non-Neutrality of Money," mimeo, Pitzer College, 1987.

Rotemberg, Julio J., "The New Keynesian Microfoundations," in Stanley Fischer, ed., *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press, 1987, pp. 69–104.

Siow, Aloysius, "Coordinating Hours of Work," mimeo, Columbia University, 1987.

Summers, Lawrence, "Should Keynesian Economics Dispense with the Phillips Curve?" in Rod Cross, ed., *Unemployment, Hysteresis, and the Natural Rate Hypothesis*, Oxford: Blackwell, 1987, pp. 11–25.

Woodford, Michael, "Indeterminacy of Equilibrium in the Overlapping Generations Model: A Survey," mimeo, Columbia University, May 1984.