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THE MACROECONOMIC IMPLICATIONS OF LABOR CONTRACTING WITH ASYMMETRIC INFORMATION

by

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The Macroeconomic Implications of Labor Contracting with Asymmetric Information

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I. INTRODUCTION AND SUMMARY

Monetary models of the business cycle are designed to explain certain stylized facts and to make a case for a particular view about the nature of employment fluctuations and optimal monetary policy. Two popular paradigms are the "islands models" of Lucas (1972, 1973) and Barro (1976) and the "disequilibrium contract models" of Gray (1976) and Fischer (1977). Both paradigms have been developed extensively, and their macroeconomic implications are widely known.[1/]

Lucas (1981) and Barro (1977) have been critical of the disequilibrium contract models because the wage and employment rules postulated in these models are not derived in a welfare-maximizing framework. Lucas concludes that, "None of these models offers an explanation as to why people should choose to bind themselves to contracts which seem to be in no one's self-interest, and my conjecture is that when reasons for this are found they will reduce to the kind of information difficulties already stressed in my 1972 article."

A new paradigm is now emerging out of the old "implicit contract models" of Azariadis (1975), Baily (1974) and Gordon (1974). The old implicit contract models are not monetary models; that is, monetary fluctuations (or fluctuations in aggregate demand) have no effect on employment or output. However, Calvo and Phelps (1977) have shown that the imposition of certain informational asymmetries will convert these implicit contract models into monetary models. Calvo and Phelps (1977) assumed that firms observe productivity disturbances directly while workers do not; other asymmetries will do as well. The new monetary paradigm that results addresses the criticism of Barro and Lucas; contracts are efficient in the Paretian sense (given the incomplete information structure). In addition, the conjecture of Lucas appears to have been borne out; the new contract models ride on the familiar confounding of real and monetary disturbances. Here, the aggregate price level (which is observed without delay) gives workers incomplete information about the local productivity disturbances they are assumed not to observe. We leave it to the reader to decide whether or not it is reasonable to assume that local information that is private to the firm can have an aggregate component that is partially revealed by the price level. The new paradigm rides on just such an assertion.

Our purpose here is to draw out the macroeconomic implications of this new paradigm.[2/] We ask whether the "asymmetric-information contract models" are consistent with a set of stylized facts, and we examine the implications for monetary policy. Where possible, we compare the implications of the new paradigm with those of the more familiar paradigms.

We take as stylized facts that: (1) An unanticipated increase in the money supply (or aggregate demand) will produce an unanticipated increase in the general price level that is associated with an increase in employment and output.[3/] (2) Real wages may move countercyclically (as in Canada, Japan and most European countries), or they may show little cyclical pattern at all (as in the U.S.).[4/] (3) Whatever the cyclical pattern, real wage variation is small.[5/] The asymmetric-information contract model presented below is consistent with the second and third facts, but it does not appear to be consistent with the first.

Our model also implies that employment will be too low (compared with a complete information structure) in bad states of nature. The policy implications of the new paradigm are virtually identical to those of the Gray (1976) contract-cum-indexing model, and rather at odds with the implications of the islands paradigm. As Lucas conjectured, the new contract models ride on a signal extraction problem. But the signal here is the aggregate price level, which gives incomplete information about local productivity disturbances. In the islands paradigm, local prices give incomplete information about the aggregate price level (which is observed with delay). The islands paradigm suggests that monetary policy should stabilize the aggregate price level to improve the quality of the local price signals; the new paradigm suggests that monetary policy ought to stablize aggregate demand to improve the quality of the aggregate price signal.

Our paper proceeds as follows: In section II, we describe the basic framework of implicit contract models. In section III, we review briefly the symmetric-information contracts of Azariadis, Baily and Gordon. In section IV, we derive the optimal asymmetric-information contract, completing the analysis begun by Calvo and Phelps (1977), and we discuss its macroeconomic implications when the model is closed with a simple velocity equation. Finally, in section V, we present a numerical example.

II. THE BASIC FRAMEWORK OF IMPLICIT CONTRACT MODELS

Firms and workers enter into contractual relationships to share risk. Workers are assumed to have little or no access to financial markets and are thus unable to insure themselves against variations in income resulting from business fluctuations. Firms on the other hand are assumed to have access to financial markets and are better able to hedge their risks. Participation in financial markets is not modelled directly (and this may be a shortcoming of our analysis). Instead it is implicit in the assumption that workers are more risk averse than firms. Here, for analytical convenience, we assume that firms are actually risk neutral. Firms insure workers against variations in income with labor contracts written prior to the realization of real and monetary shocks.

The production function of the typical firm is

(1) $y = \theta f(n)$,

where n is the fraction of the firm's work force that is actually working and θ is a random variable. We assume that there is no job sharing; a worker is either employed, or he is laid off.[6/] The shock θ can take two values, θ_1 and θ_2, with probabilities π_1 and π_2, respectively. It is assumed that $\pi_i \in (0, 1)$ for $i = 1, 2$, $\pi_1 + \pi_2 = 1$, and $\theta_1 < \theta_2$. θ_1 is the "bad" state of nature. The function $f(\cdot)$ is increasing, strictly concave, twice continuously differentiable, and $f'(n) \to \infty$ as $n \to 0$.

The utility of the typical worker is given by $V(c,\ell)$, where c represents consumption and ℓ represents leisure. There is no job sharing, so ℓ can only take two values, 0 if the worker is employed and 1 if the worker is laid off. Define

(2) $U(w) \equiv V(\bar{c}+w,0)$

(3) $K \equiv V(\bar{c}, 1)$,

where w is the real wage and $\bar{c}$ is non-labor income. U(w) is the utility of an employed worker earning wage w, and K is the utility of a laid-off worker. The function $V(c,\ell)$ is increasing in ℓ, so $K > U(0)$. The function $U(\cdot)$ is increasing, strictly concave, twice continuously differentiable, and $U'(w) \to 0$ as $w \to \infty$.

At the beginning of each period the firm and its workers agree to a contract specifying a wage rule, $w(\theta,p)$, and an employment rule, $n(\theta,p)$. The rules are functions of the real shock and the aggregate price level. The reason for including the price level will be discussed later in this section. Workers are assumed to be mobile, so each of the identical firms must offer the same contract.[7/] Lay-offs are assumed to be random, so for a given state, (θ,p), a worker has probability $n(\theta,p)$ of being employed.

Def. 1. A contract $C = \{n(\theta,p),w(\theta,p)\}$ is said to be feasible if

$$U[w(\theta,p)] > K$$

$$\theta f[n(\theta,p)] - n(\theta,p)w(\theta,p) > 0 \tag{4}$$

$$0 < n(\theta,p) < 1$$

for every possible (θ,p).

The first condition asserts that workers prefer working to being laid off at the specified wage. The second condition requires that the firm make a positive profit. These conditions rule out contracts that give either the firm or its workers an obvious incentive to renege if a bad state occurs. However, it should also be noted that a laid-off worker will have an incentive to offer to work for slightly less than the specified wage if $U(w) > K$. The firm will be tempted to accept this offer and lay off someone else. Having ruled out the most egregious cases, we still have to simply assume that the contract is binding for the firm. It will be assumed that there exist constants n and w such that $U(w) > K$, $\theta f(n) - wn > 0$, and $0 < n < 1$. This will ensure that a feasible contract exists.

Under the contract C, the firm's expected profit is

$$P(C) \equiv E\{\theta f[n(\theta,p)] - w(\theta,p)n(\theta,p)\}, \tag{5}$$

and the worker's expected utility is

$$I(C) \equiv E\{n(\theta,p)U[w(\theta,p)] + [1 - n(\theta,p)]K\}. \tag{6}$$

Expectations are taken with respect to the joint distribution of θ and p which will be discussed in some detail below.

We examine two information structures in the sections that follow. With symmetric information both the firm and its workers observe the real shock θ ex post. With asymmetric information only the firm observes θ ex post. However, even if θ is private to the firm, workers can obtain some information about it by observing movements in the aggregate price level, for p is assumed to be a noisy signal of real disturbances. Before going on to define and derive the optimal contract under each of the information structures, we want to be more precise about the information embodied in p.

To do this, we close the model with the simple velocity equation

$$(7) \qquad mv = py = p\theta f[n(\theta,p)],$$

where m is the money stock and v is a continuous random variable representing a monetary disturbance (or a fluctuation in aggregate demand). In all of the contracts we examine, it turns out that a decrease in θ creates an excess supply of money which can be eliminated by increasing p. So at a given p and v, a decrease in θ creates an excess supply of money and p must rise. Thus, if v is not "too" large and "too" strongly correlated with θ, a higher p will be interpreted by workers as an increase in the probability that the bad state θ has occurred; letting $\pi_1(p)$ and $\pi_2(p)$ be the probabilities of θ_1 and θ_2, respectively, given that the price level is equal to p,

$$(8) \qquad \frac{d\pi_1(p)}{dp} > 0, \quad \frac{d\pi_2(p)}{dp} < 0.$$

To simplify matters further it will also be assumed that the support of v is large enough so that p is always an imperfect signal of θ, that is $0 < \pi_i(p) < 1$ for i = 1, 2. Then equation (8) holds with strict inequality.

The asymmetric-information contract model of section IV rides on the fact that the aggregate price level conveys some information about each individual firm's productivity shock. The firm's private information must have an aggregate component; this would appear to be a strong assumption. By contrast, the private information in the islands paradigm is a "local" price that has no aggregate component; this may be a more reasonable assumption.

III. CONTRACTING UNDER SYMMETRIC INFORMATION

In the implicit contract models of Azariadis (1975) and Baily (1974), both the firm and its workers observe the productivity shock θ. There is no need to use the information embodied in the price level when determining optimal wage and employment rules. As a result, models with a symmetric-information structure serve only as explanations of real business cycles. We review such a model briefly in this section; the symmetric-information solution serves as a benchmark in our discussion of the asymmetric-information case to follow.

Def. 2. A contract is said to be Pareto optimal under symmetric information if it solves

$$(9) \quad \max_{C} \{\lambda P(C) + (1-\lambda)I(C)\}$$

subject to (4) (the feasibility constraints), where $\lambda \in [0,1]$.

By assumption the set of feasible contracts is nonempty; hence, for a given λ, there exists a unique solution to (9). We also assume that the solution is interior, and thus, satisfies the first-order conditions.[8/]

$$(10)\quad \begin{aligned} &\lambda\{\theta_i f'[n(\theta_i,p)] - w(\theta_i,p)\} + (1-\lambda)\{U[w(\theta_i,p)] - K\} = 0 && i = 1, 2; \forall p \\ &-\lambda + (1-\lambda)U'[w(\theta_i,p)] = 0 && i = 1, 2; \forall p. \end{aligned}$$

Rearranging (10), the optimal symmetric-information contract, C^S, is characterized by

$$(11a)\quad w(\theta_i,p) = \overline{w} \quad \text{where } U'(\overline{w}) = \frac{\lambda}{1-\lambda} \qquad i = 1, 2; \forall p$$

$$(11b)\quad n(\theta_i,p) = n_i \quad \text{where } \theta_i f'(n_i) = \overline{w} - [U(\overline{w})-K]/U'(\overline{w}) \qquad i = 1, 2; \forall p$$

Thus, by (11a), the real wage is constant across states; the firm insures the workers against real wage variation. By (11b), the level of employment is a monotonic function of θ. Sargent (1979, ch. 8) explains why the firm does not insure workers completely against lay-offs. The real wage exceeds the marginal product of labor in each state. Workers accept a positive probability of unemployment in exchange for this premium.

It is apparent from (11) that neither the real wage nor employment responds to fluctuations in the price level. A monetary disturbance, therefore, has no real effects. Thus, contracting under symmetric information cannot explain our first stylized fact. Employment does respond to fluctuations in θ, so contracting with symmetric information provides a real business cycle model. Real wages are fixed at $\overline{w}$, so if business cycles are indeed generated by real disturbances, then we have an explanation of our third stylized fact.

It should be noted that employment fluctuations are ex post, as well as ex ante, optimal in the following sense. After the realization of θ, but before the specification of which laborers are to be laid off, the contract cannot be rewritten so as to make either the firm or any one worker better off without some other worker or the firm being made worse off.

IV. CONTRACTING UNDER ASYMMETRIC INFORMATION

If the realization of θ is the private information of the firm, and workers never observe it directly, then the firm has a credibility problem. The optimal symmetric-information contract, C^s, is written in terms of the unobservable θ, and the firm may have an incentive to report a lower value of θ than has actually occurred. This is because the contract C^s calls for a real wage that is higher than the marginal product of labor. By understating θ, the firm can lower employment and may increase profits. If the firm cannot be relied upon to simply tell the truth, say for altruistic reasons, then C^s is not implementable.

In this section, we restrict our attention to contracts that are, in Hurwicz's (1972) terminology, "incentive compatible". A contract is said to be incentive compatible if the firm has no incentive to misreport its private information. At first glance, this may appear to be an overly restrictive way of dealing with the credibility problem; workers may be better off in a contract where the firm is systematically misrepresenting θ. However, it turns out that there is no loss of generality here; any contract that is not incentive compatible can be rewritten in terms of one that is.[9/]

In this section, we also restrict our attention to contracts that last only one period, and here we are being overly restrictive. Townsend (1982) has shown there is a gain from enduring relationships that can be captured in multiperiod contracts. Some insights as to why this is so can be gotten by noting that firms may not be able to credibly understate θ period after period if workers know the probability distribution of θ.[10/] Contractual arrangements can make reporting a low θ in the first period limit the options of the firm in subsequent periods. We will not explore these possibilities further, but we do note that Townsend's reason for the existence of long-term contracts contrasts sharply with views coming from the disequilibrium contract models. The latter stress costs of negotiation.[11/]

With asymmetric information and incentive-compatibility problems, there is a need to use the information embodied in the price level when designing optimal wage and employment rules. The price level provides a noisy signal of θ; the signal is noisy because the price level also moves in response to monetary disturbances (or fluctuations in aggregate demand). Note that if contracts index wages and employment to the price level, then monetary disturbances will pass to real economic activity. The asymmetric-information contract model is a monetary model.

Both the new contract paradigm and the islands paradigm make money matter by imposing an information constraint on the economy, and like a technology constraint, these information constraints impose welfare costs. In both paradigms, absent information constraints, agents would not let monetary fluctuations affect real economy activity. The ultimate goal of monetary policy is then to make the information constraint non-binding (by improving the quality of local price signals in the isalnds paradigm and by improving the quality of the aggregate price signal in the contract paradigm) and return to an economy in which monetary fluctuations do not matter.

We will proceed as follows: First, we discuss incentive compatibility in more detail; it turns out that several properties of the optimal contract follow directly from the incentive-compatibility restrictions. Next, we characterize the optimal contract, illustrate the response of employment to a monetary disturbance, and discuss the cyclical behaviour of real wages. Finally, we discuss the implications for monetary policy.

Incentive Compatibility

Def. 3. A contract is said to be incentive compatible if

(12a) $\theta_1 f[n(\theta_1,p)] - w(\theta_1,p)n(\theta_1,p) \geq \theta_1 f[n(\theta_2,p)] - w(\theta_2,p)n(\theta_2,p)$

(12b) $\theta_2 f[n(\theta_2,p)] - w(\theta_2,p)n(\theta_2,p) \geq \theta_2 f[n(\theta_1,p)] - w(\theta_1,p)n(\theta_1,p)$.

The first equation says the firm is not tempted to report θ_2 when θ_1 has occurred; the second equation says the firm is not tempted to report θ_1 when θ_2 has occurred.

The optimal symmetric-information contract, C^S, violates the second condition if θ_1 is "close" to θ_2.

Prop. 1 For $\theta_2 - \theta_1$ sufficiently small, $\theta_2 f(n_2) - \bar{w}n_2 < \theta_2 f(n_1) - \bar{w}n_1$, where n_i, i = 1, 2 and $\bar{w}$ are given by (11).

If the support for θ were continuous, no qualification would be necessary; the reasoning given earlier would suffice. The proposition is proven in the Appendix.

The incentive-compatibility constraints themselves determine several characteristics of the contracts considered below.

Prop. 2 If $C = \{w(\theta,p),n(\theta,p)\}$ is incentive compatible, then

(i) $n(\theta_2,p) > n(\theta_1,p)$ $\forall p$

(ii) $w(\theta_2,p)n(\theta_2,p) > w(\theta_1,p)n(\theta_1,p)$ $\forall p$

(iii) $\theta_2 f[n(\theta_2,p)] - w(\theta_2,p)n(\theta_2,p) > \theta_1 f[n(\theta_1,p)] - w(\theta_1,p)n(\theta_1,p)$ $\forall p$

Employment, the wage bill and profits are all higher in the good state than in the bad. These results follow directly from (12) and the fact that both (12a) and (12b) cannot hold simultaneously.[12/] The proof is left to the reader.

Optimal Contract

Def. 4. A contract is said to be Pareto optimal under asymmetric information if its solves problem (9) subject to constraints (4) and (12).

It turns out that if the symmetric-information contract is not implementable, then (12b) must be binding, but (12a) is not.

Prop. 3: $\gamma_2(p) > \gamma_1(p) = 0$, where $\gamma_1(p)$ and $\gamma_2(p)$ are the Lagrange multipliers for (12a) and (12b) respectively in the Pareto maximization problem.

This is, of course, what one would suspect from Prop. 1; the problem is to keep the firm from understating θ. This proposition is also proven in the Appendix.

The optimal contract is derived as follows. For every possible realization of p, choose $\{n(\theta_i,p),\ w(\theta_i,p),\ \gamma_2(p)\}_{i=1}^{2}$ to maximize

$$
\begin{aligned}
(13)\quad & \lambda \sum_{i=1}^{2} \pi_i(p)\{\theta_i f[n(\theta_i,p)] - w(\theta_i,p)n(\theta_i,p)\} \\
& + (1-\lambda) \sum_{i=1}^{2} \pi_i(p)n(\theta_i,p)\{U[w(\theta_i,p)] - K\} \\
& + \gamma_2(p)\{\theta_2 f[n(\theta_2,p)] - w(\theta_2,p)n(\theta_2,p) - \theta_2 f[n(\theta_1,p)] + w(\theta_1,p)n(\theta_1,p)\}
\end{aligned}
$$

subject to (4).

It was assumed that there exists a contract $\{n,w\}$ which satisfies (4). This contract clearly satisfies (12b); hence the set of feasible contracts under asymmetric information is nonempty. We now further assume that $w(\theta_1,p) - \dfrac{U[w(\theta_1,p)] - K}{U'[w(\theta_1,p)]} > 0\ \forall p$ at the solution. (This is equivalent to assuming that the elasticity of expected utility in state (θ_1,p) with respect to wages is greater than or equal to the elasticity of expected utility with respect to employment.) This condition is sufficient to insure that the second-order conditions for a maximum are satisfied. It is assumed that the unique solution to (13) is interior with respect to the feasibility constraints. Such a solution satisfies the first-order conditions (12b) and

(14a) $\lambda\pi_1(p)\{\theta_1 f'[n(\theta_1,p)] - w(\theta_1,p)\} + (1-\lambda)\pi_1(p)\{U[w(\theta_1,p)] - K\}$
$- \gamma_2(p)\ \{\theta_2 f'[n(\theta_1,p)] - w(\theta_1,p)\} = 0$

(14b) $[\lambda\pi_2(p) + \gamma_2(p)]\{\theta_2 f'[n(\theta_2,p)] - w(\theta_2,p)\}$
$+ (1 - \lambda)\pi_2(p)\{U[w(\theta_2,p)] - K\} = 0$

(14c) $-\lambda\pi_1(p) + \gamma_2(p) + (1 - \lambda)\pi_1(p)U'[w(\theta_1,p)] = 0$

(14d) $-\lambda\pi_2(p) - \gamma_2(p) + (1 - \lambda)\pi_2(p)U'[w(\theta_2,p)] = 0.$

While it is impossible to solve for closed-form expressions for $w(\theta,p)$ and $n(\theta,p)$, many interesting results can be derived implicitely from the first order conditions.

Prop 4. If $w(\theta,p)$ and $n(\theta, p)$ are the optimal wage and employment rules, then

(i) $w(\theta_1,p) > \bar{w} > w(\theta_2,p)$,

(ii) $n(\theta_1,p) > (<)\ n_1$ as $\theta_2 f'[n(\theta_1,p)] - w(\theta_1,p) < (>)\ 0$

(iii) $n(\theta_2,p) < n_2$

where $\bar{w}$ is the optimal symmetric-information wage and n_1 and n_2 are the optimal symmetric-information employment levels.

<u>Proof</u> (i) follows from (11a), (14c), and (14d). (ii) and (iii) are discussed later in this section.

It may seem paradoxical that the real wage is higher in the bad state than in the good state.[13/] However, the reason is readily made apparent. To keep the firm from understating θ in the good state, the optimal contract must make the bad state less attractive; one way it does so is by making $w(\theta_1,p) > w(\theta_2,p)$.

<u>Prop. 5.</u> Relative to symmetric information, the optimal contract under asymmetric information is characterized by

(i) Underemployment in the bad state (θ_1)

(ii) Efficient employment in the good state (θ_2).

<u>Proof</u> To show (i), solve (14c) for $\gamma_2(p)$ and substitute into (14a) to get

$$(15) \quad \theta_1 f'[n(\theta_1,p)] = w(\theta_1,p) - \frac{U[w(\theta_1,p)] - K}{U'[w(\theta_1,p)]}$$

$$+ (\theta_2-\theta_1) \frac{\frac{\lambda}{1-\lambda} - U'[w(\theta_1,p)]}{U'[w(\theta_1,p)]} f'[n(\theta_1,p)]$$

$$> w(\theta_1,p) - \frac{U[w(\theta_1,p)] - K}{U'[w(\theta_1,p)]}$$

where the inequality follows from (14c) and the fact that $\gamma_2(p) > 0$. Thus, by (11b), which gives the optimal tradeoff between labor and leisure when there is no information asymmetry, the marginal product of labor is too high. To show (ii), solve (14d) for $\gamma_2(p)$ and substitute into (14b) to get

$$(16) \quad \theta_2 f'[n(\theta_2,p)] = w(\theta_2,p) - \frac{U[w(\theta_2,p)] - K}{U'[w(\theta_2,p)]} .$$

Note that Prop. 4 states that $n(\theta_1,p)$ may be greater than n_1. The import of Prop. 5 is that given $w(\theta_1,p)$, $n(\theta_1,p)$ is too low to represent an efficient trade-off between labor and leisure (relative to full information).

The results in Prop. 5 are dependent upon our assumption about job sharing and, in general, the specification of preferences. Suppose instead that we model the representative worker with a divisible endowment of labor. Employment is efficient in one state and inefficient in the other. If income effects on leisure are negative, we again obtain underemployment in the bad state. If income effects are positive, we obtain overemployment in the good state. If there are no income effects on leisure, it turns out that the optimal symmetric-information contract is incentive compatible. See Chari (1983) and Cooper (1983) for a discussion of this. Many studies use the utility function $U[w-g(n)]$, which has no income effects, and assume the firm is also risk averse; in this case the symmetric-information contract is again incentive incompatible.[14/]

<u>Prop. 6</u>. As the price level becomes a perfect signal of the productivity shock, the optimal asymmetric information contract approaches the optimal symmetric-information contract.

<u>Proof</u> Note that by (14c) and (14d),

$$(17) \quad \sum_{i=1}^{2} \pi_i(p)U'[w(\theta_i,p)] = \frac{\lambda}{1-\lambda}.$$

Thus as $\pi_i(p) \to 1$, $w(\theta_i,p) \to \overline{w}$, for i = 1, 2. Equations (15) - (17) imply that

$n(\theta_i, p) \to n_i$ as $\pi_i(p) \to 1$.

The Real Effects of a Monetary Disturbance

An unanticipated and unobserved increase in the velocity v will increase the price level p, and this will be used in the asymmetric information contract as a signal that the bad state θ_1 is more likely to have occurred. In other words, a positive shock to velocity will increase the conditional probability $\pi_1(p)$. In this section we discuss the impact of price and $\pi_1(p)$ changes on employment and wages. Some of the results depend on the sign of $\theta_2 f'[n(\theta_1, p)] - w(\theta_1, p)$. In what follows we will assume that this quantity is everywhere strictly negative. The other case will be considered in the Appendix. A numerical example in section V will suffice to show that the assumption is not vacuous.

Prop. 7.

(i) $\frac{\partial w(\theta_i, p)}{\partial \pi_1(p)} < 0$ $\qquad i = 1, 2$

(ii) $\frac{\partial n(\theta_i, p)}{\partial \pi_1(p)} < 0$ $\qquad i = 1, 2$

Proof. To derive (i) and (ii) required the incredibly tedious but straightforward total differentiation of the first-order conditions (12b) and (14). Details are available from the authors. The assumption

$$\theta_2 f'[n(\theta_1, p)] - w(\theta_1, p) < 0$$

is a necessary and sufficient condition for $\partial n(\theta_1, p)/\partial \pi_1(p) < 0$.[15/]

By Prop. 7, in conjunction with (8), it follows that wages and employment in each state decrease with an increase in p. The basic story that seems to emerge from all of this is that a positive monetary disturbance raises the price level and is taken as a noisy signal that the bad state θ_1 may have occurred. Employment and real wages fall, no matter what state has actually occurred. The negative effect on employment runs counter to our first stylized fact.

Prop. 7 can also be used to verify our earlier assertion that p and θ are negatively correlated if velocity is not "too" large and "too" highly correlated with θ. To see this, suppose the reverse is true and high values of p are associated with θ_2. Then $d\pi_1(p)/dp < 0$ and in order for (7) to hold it must be the case that $\partial n(\theta_i,p)/\partial p = [\partial n(\theta_i,p)/\partial\pi_1(p)][\partial\pi_1(p)/\partial p] < 0$. By Prop. 7, this is a contradiction.

Cyclical Behavior of Real Wages

Fluctuations in the real wage and employment are generated by changes in productivity in addition to unanticipated movements in velocity. As we noted in the introduction, the stylized fact is that wages and employment are negatively correlated in most countries other than the United States, and either uncorrelated or mildly positively correlated in the United States. In addition, there is a perception that there is not much cyclical variation in wages, whatever the correlation. Here we draw out the implications of the asymmetric-information contract model and compare them to the implications of the disequilibrium contract model of Gray (1976) and Fischer (1977).[16]

The implications of the asymmetric-information contract model are illustrated in figure 1. The higher curve represents the locus of wage and employment levels for the bad state and the lower curve represents the locus of wage and employment levels for the good state. By Prop. 7, as $\pi_1(p)$ rises from the 0 to 1, $w(\theta_i,p)$ and $n(\theta_i,p)$ fall for i = 1, 2. Thus $w(\theta_i,p)$ and

Asymmetric Information Contract Model

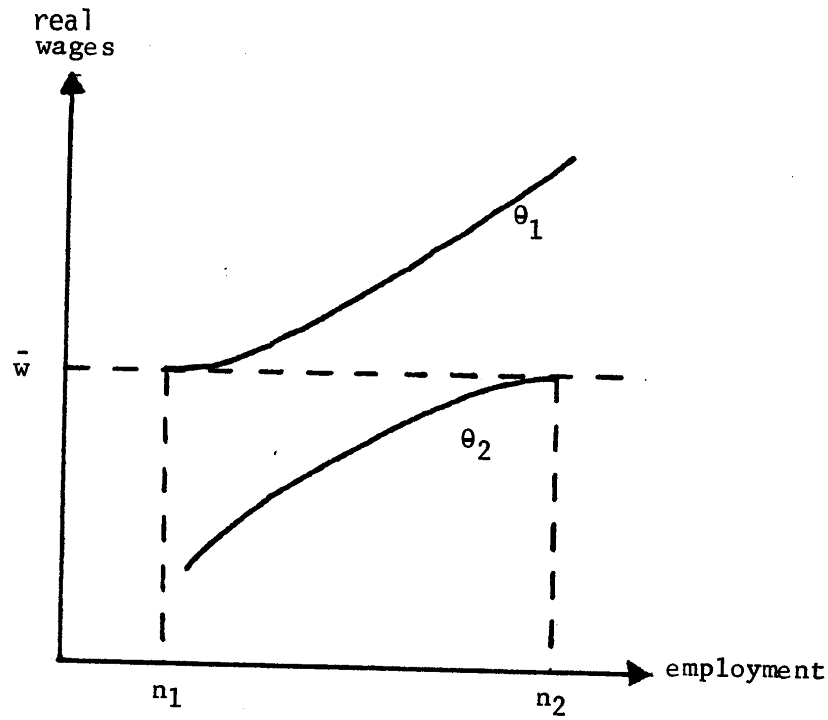


Figure 1

Disequilibrium Contract Model

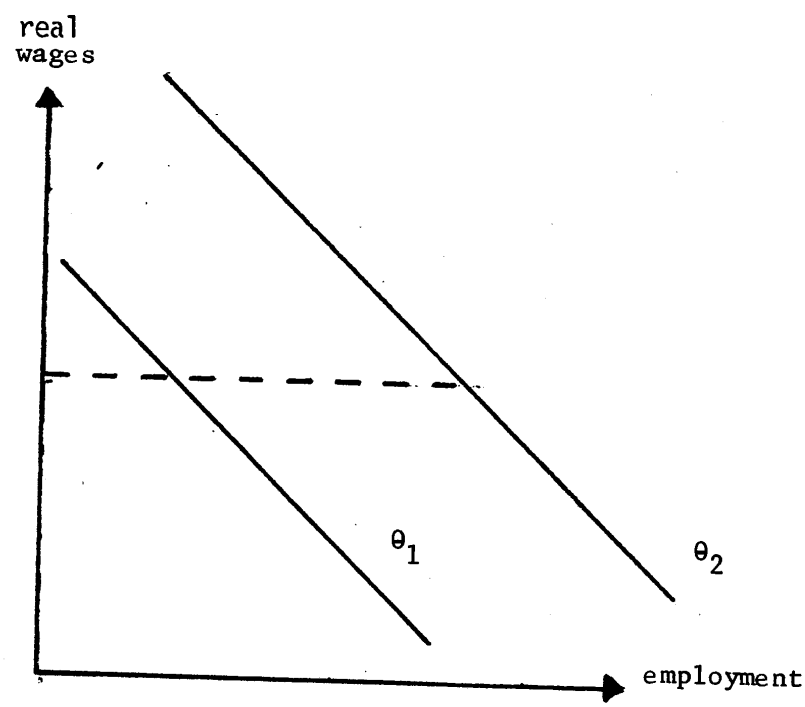


Figure 2

$n(\theta_i, p)$ are positively related and both curves in figure 1 must be upward sloping. By Prop. 6, as $\pi_i(p) \to 1$, $n(\theta_i, p) \to n_i$ and $w(\theta_i, p) \to \bar{w}$. Thus $(n_i, \bar{w})$ must be a point on the locus corresponding to state θ_i. By Prop. 4, $w(\theta_1, p) > \bar{w} > w(\theta_2, p)$; hence the locus for the bad state must lie above $\bar{w}$ and the locus for the good state must lie below $\bar{w}$. Note from figure 1 that it must be the case that $n(\theta_1, p) > n_1$ and $n(\theta_2, p) < n_2$, as assertd in Prop. 4.

If actual observations were scattered uniformly on each curve we would observe a positive correlation between wages and employment. However, we have a negative correlation between p and θ; hence observations should be clustered around the high probability points at the bottom of the bad state curve and the top of the good state curve. It is quite consistent with this model to observe a negative correlation between wages and employment. The degree of variation of wages depends on the flatness of the two curves, but it does not seem inconsistent with our model to observe little cyclical variation in wages.

The implications of the disequilibrium contract model are illustrated in figure 2. In this model, the nominal wage is fixed in a contract before p and θ are observed, and once p and θ are observed, firms are allowed to maximize profits. They hire (or lay off) along the relevant marginal productivity curve pictured in figure 2. The nominal wage is set at a level that is expected to achieve some real wage target, w^*.[17/] If actual observations were scattered uniformly on each curve we would observe a negative correlation between wages and employment. However, the negative correlation between p and θ implies that actual realizations should be clustered around the lower portion of the lower curve and around the upper portion of the upper curve. A positive correlation between wages and employment is consistent with this paradigm. Little cyclical variation in wages is also consistent with this framework.

To summarize, both the asymmetric-information contract model and the disequilibrium contract model seem capable of explaining the stylized facts about the cyclical behavior of real wages.

The Implications for Monetary Policy

Information constraints are like technology constraints; they limit welfare. Prop. 5 states that the asymmetric-information structure we have imposed results in too little employment in the bad state, θ_1. However, Prop. 6 states that if the price level is a perfect signal of the productivity shock, the symmetric-information contract is implementable. If p reveals θ to the workers, then the information constraint is not binding. The normative implication of this paradigm is that monetary policy should make p a good signal of θ.

In equation (9), it is the unobserved disturbance v that makes p a noisy signal of θ. If the monetary authority has superior information, it can improve the quality of the signal. For example, the policy rule

(18) $m = 1/v$

would make p a perfect signal of θ. The monetary authority should offset monetary disturbances (or fluctuations in aggregate demand).

In the islands model paradigm, the information constraint is that local producers do not know the aggregate price level; local prices are a noisy signal of p. This suggests that the monetary authority ought instead to use its superior information (if it has any) to peg the price level, making it predictable.

Disequilibrium contract models that do not incorporate productivity disturbances have policy implications that are similar to those of the islands model paradigm; losses are associated with errors in predicting p.[18/] Models incorporating producitivity disturbances and Gray's (1976) indexing scheme have policy implications identical to those of the asymmetric-information contract model discussed here; the price level is used by Gray's contractors as a noisy signal of the productivity disturbance.

V. EXAMPLE

In this section we give a simple example. Let

$$f(n) = \sqrt{n} \qquad K = 7/16$$

$$U(w) = \sqrt{w} \qquad \theta_1 = 3/16$$

$$\lambda = 1/2 \qquad \theta_2 = 1/4.$$

Then the optimal symmetric-information contract is

$$\bar{w} = 1/2 \qquad n_2 = 4/9$$

$$n_1 = 1/4$$

This is easily seen to be non-incentive compatible.

It is not possible to solve analytically for the optimal asymmetric-information contract. Numerical simulation gives Figures 3 and 4 which depict wages and employment for each θ as a function of $\pi_1(p)$.

Figure 3
Real Wages

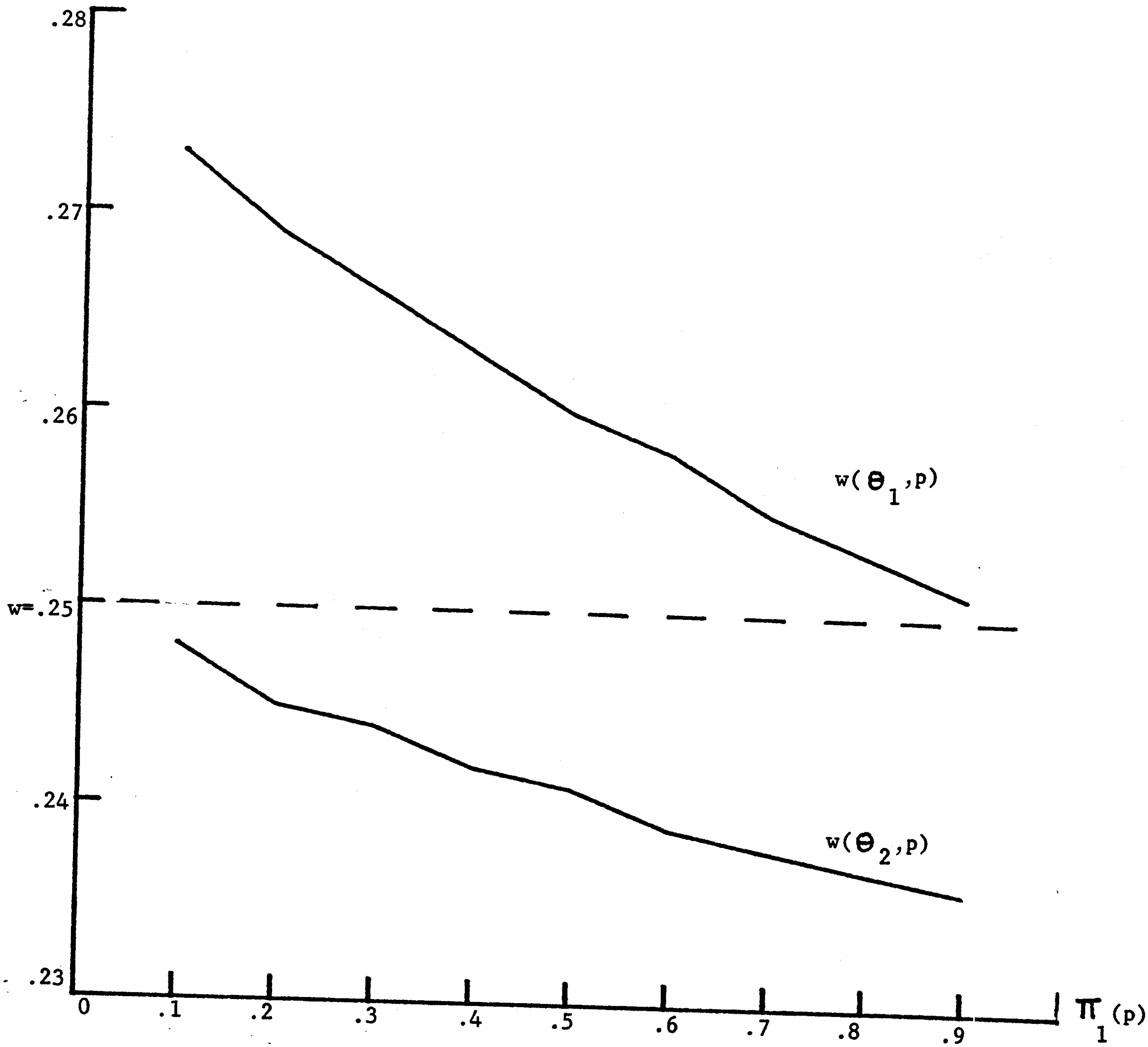
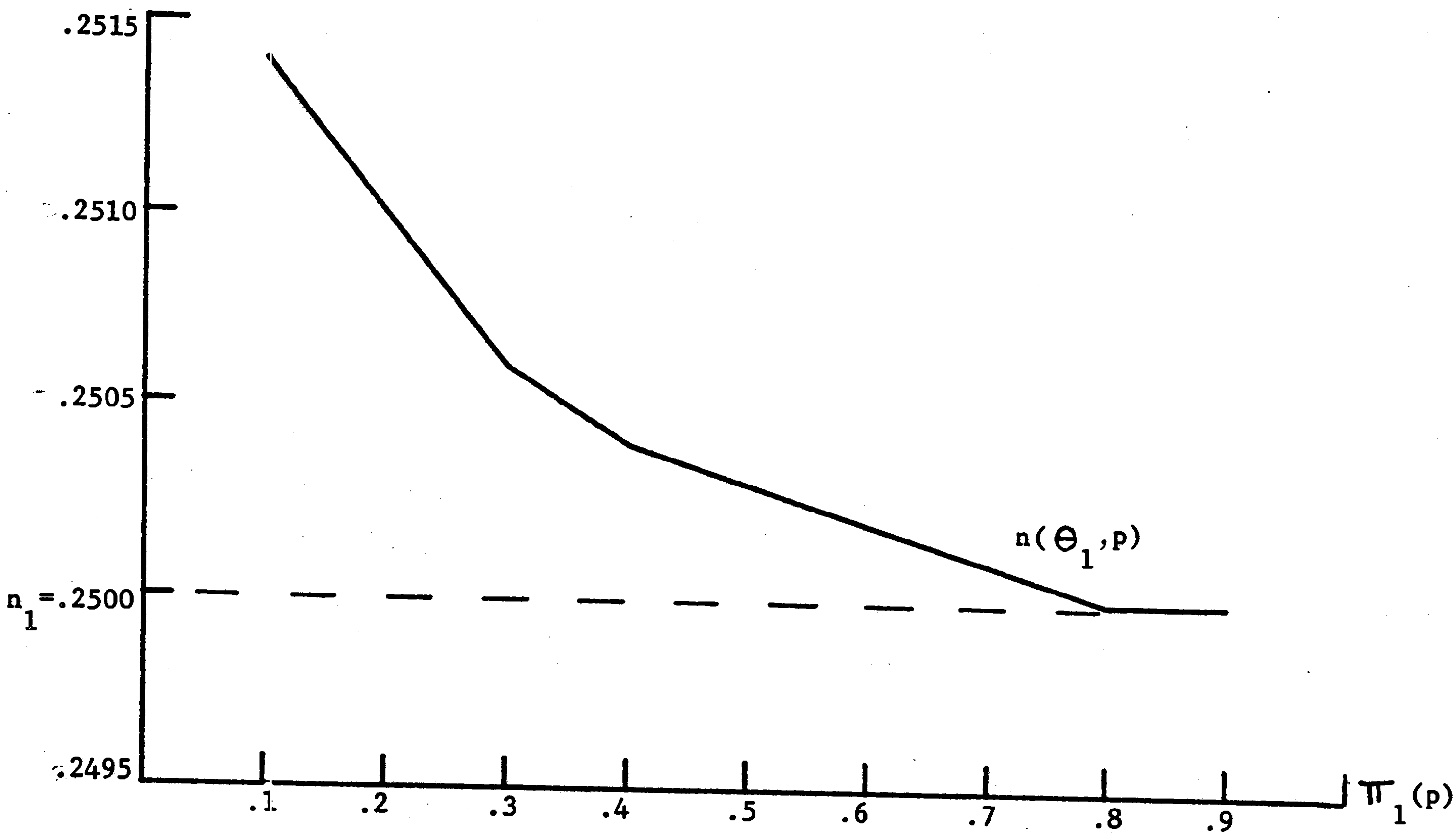
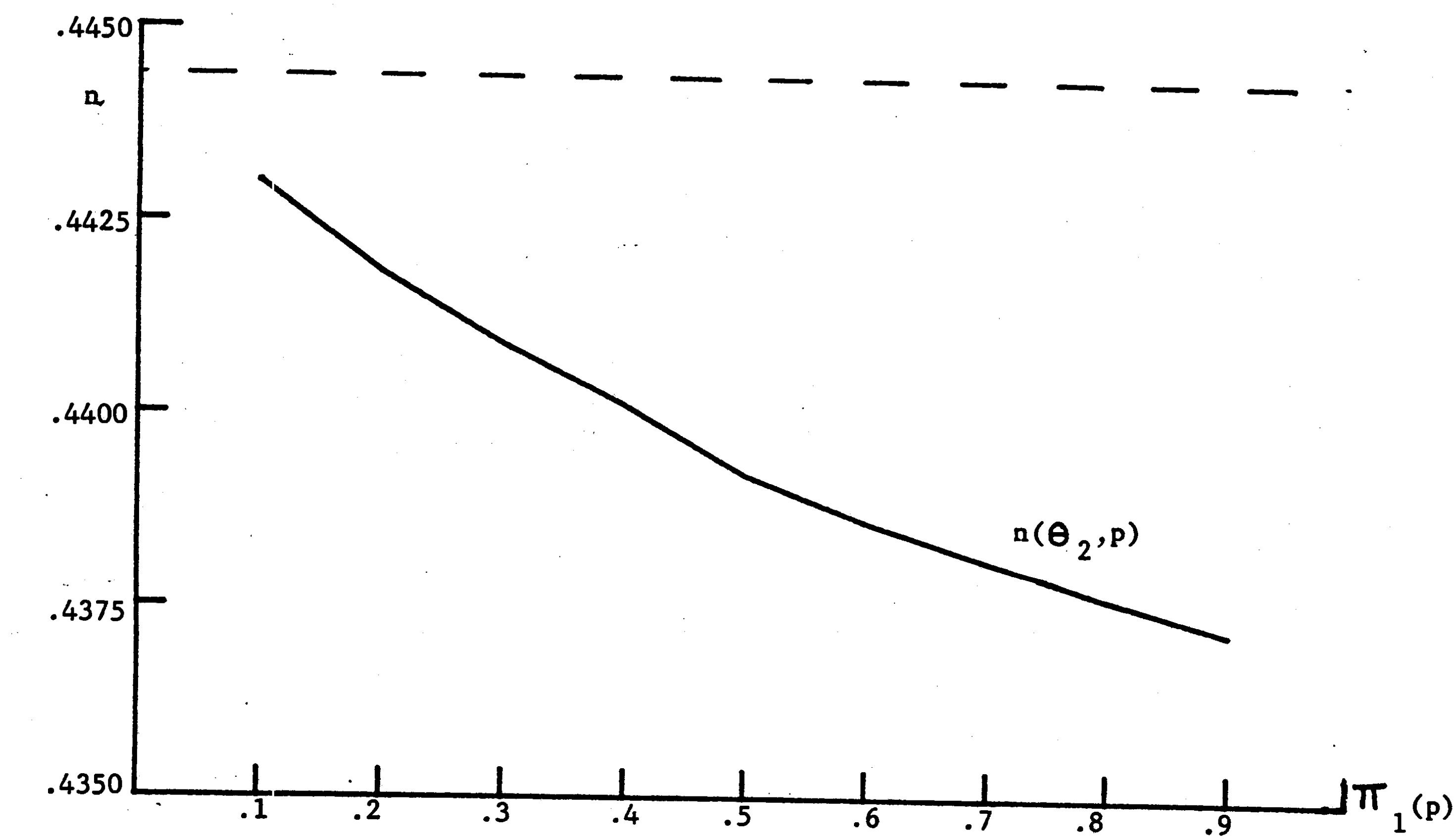


Figure 4
Employment





APPENDIX

Proof of Prop 1. The inequality

$$\theta_2 f[n(\theta_2,p)] - \bar{w}n(\theta_2,p) < \theta_2 f[n(\theta_1,p)] - \bar{w}n(\theta_1,p)$$

holds (by the Mean-Value theorem) if

$$\theta_2 f'(\tilde{n}) < \bar{w} \; ; \forall \tilde{n} \in (n(\theta_1,p), n(\theta_2,p)).$$

$$<=> -\frac{\theta_2}{U'(\bar{w})}[U(\bar{w}) - K] < (\tilde{\theta} - \theta_2)\bar{w},$$

where $\tilde{\theta} = [\bar{w} - \frac{U(\bar{w})-K}{U'(\tilde{w})}]/f'(\tilde{\theta})$.

Clearly $\tilde{\theta} \in (\theta_1, \theta_2)$; hence this must be true for $\theta_2 - \theta_1$ sufficiently small.

Proof of Prop. 3. By contradiction.

Suppose Prop. 3 does not hold. Then $\gamma_1(p) > \gamma_2(p) = 0$. The relevant first-order conditions are (12a) and

(A1) $[\lambda\pi_1(p) + \gamma_1(p)]\{\theta_1 f'[n(\theta_1,p)] - w(\theta_1,p)\} +$
$(1 - \lambda)\pi_1(p)\{U[w(\theta_1,p)] - K\} = 0$

(A2) $-\lambda\pi_1(p)\{\theta_2 f'[n(\theta_2,p)] - w(\theta_2,p)\} + (1 - \lambda)\pi_2(p)\{U[w(\theta_2,p) - K\} -$
$\gamma_1\{\theta_1 f'[n(\theta_2,p)] - w(\theta_2,p)\} = 0$

(A3) $-\lambda\pi_1(p) - \gamma_1(p) + (1 - \lambda)\pi_1(p)U'[w(\theta_1,p)] = 0$

(A4) $-\lambda\pi_2(p) + \gamma_1(p) + (1 - \lambda)\pi_2(p)U'[w(\theta_2,p)] = 0$

By (A3) and (A4)

$$U'[w(\theta_1,p)] > U'[w(\theta_2,p)]$$

(A5) $\Rightarrow w(\theta_2,p) > w(\theta_1,p)$.

By (A1) and (A3)

(A6) $$\theta_1 f'[n(\theta_1,p)] - w(\theta_1,p) = -\frac{U[w(\theta_1,p)] - k}{U'[w(\theta_1,p)]}.$$

By (12a)

$$\theta_1 f[n(\theta_1,p)] - n(\theta_1,p)w(\theta_1,p) = \theta_1 f[n(\theta_2,p)] - n(\theta_2,p)w(\theta_2,p)$$

$$\Rightarrow \quad \theta_1\{f[n(\theta_1,p)] - f[n(\theta_2,p)]\} = n(\theta_1,p)w(\theta_1,p) - n(\theta_2,p)w(\theta_1,p) + n(\theta_2,p)w(\theta_1,p) - n(\theta_2,p)w(\theta_2,p)$$

$$\Rightarrow \quad \theta_1 f'(\tilde{n})[n(\theta_1,p) - n(\theta_2,p)] = [n(\theta_1,p) - n(\theta_2,p)]w(\theta_1,p) + n(\theta_2,p)[w(\theta_1,p) - w(\theta_2,p)],$$

where $\tilde{n} \in (n(\theta_1,p),n(\theta_2 p))$ by the Mean-Value Theorem and Prop. 2(i). Thus,

$$\theta_1 f'(\tilde{n}) - w(\theta_1,p) = n(\theta_2,p)[w(\theta_2,p) - w(\theta_1,p)]/[n(\theta_2,p) - n(\theta_1,p)] > 0$$

by (A5) and Prop 2(i). Thus,

$$\theta_1 f'[n(\theta_1,p)] - w(\theta_1,p) > 0.$$

This contradicts (A6).

<u>Case of $\theta_2 f'[n(\theta_1,p)] - w(\theta_1,p) > 0$</u>

In this case we have by total differentiation of the first-order conditions

$$\frac{\partial w(\theta_i,p)}{\partial p} < 0$$

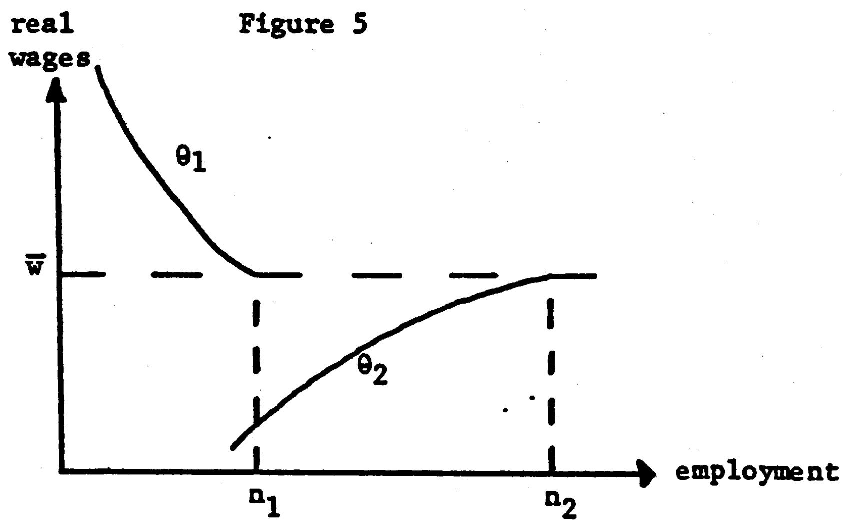
$$\frac{\partial n(\theta_1,p)}{\partial p} > 0$$

$$\frac{\partial n(\theta_2,p)}{\partial p} < 0.$$

Thus a velocity shock results in a rise in employment in the bad state and a fall in employment in the good state.

Proceeding as in the text we can graph the locus of employment-wage pairs for each θ.

Figure 5



From the figure it is clear that $n(\theta_i,p) < n_i$; thus, employment is always higher under symmetric information. The high probability points are those on the bottom of the θ_1 curve and top of the θ_2 curve. Thus, the negative relationship between wges and employment holds for this case.

Footnotes

*We would like to thank G. Calvo, E. Green, D. Henderson, R. King, P. Minford, and K. Rogoff for their helpful comments, and P. Decker who coaxed our numerical solutions out of the computer. However, the views presented here are our own; in particular, they do not necessarily represent the views of the Federal Reserve Board or any other member of its staff.

1/ See, for example the surveys of McCallum (1980) and Taylor (1980).

2/ There is already an extensive literature discussing the microeconomic implications of contracting with asymmetric information. See, for example, Hart (1983) and the references therein. The Quarterly Journal of Economics supplement Vol. 98, 1983, is almost exclusively devoted to this subject. Grossman, Hart, and Maskin (1983) show that with asymmetric information an observable aggregate shock can lead to a reduction in employment. But as far as we are aware, ours is the only attempt to complete the analysis begun by Calvo and Phelps (1977).

3/ This stylized fact is based upon emperical work by Lucas (1973), Barro (1978), Sargent (1976) and others. Fischer (1982) and Sims (1980), using vector autoregressions, find price impulses to be negatively correlated with real economic activity; however, the vector autoregression technology confounds lagged and contemporaneous correlations, and in addition, it is impossible to tell whether the price impulses are due to real or monetary disturbances.

4/ Many studies have found a procyclical pattern for U.S. real wages; see Bodkin (1969) and Lucas (1970) and the papers they reference. More recently, Canzoneri (1978) found Canadian real wages to be countercyclical. Sachs (1983) found real wages in Canada, Germany, the U.K., and Japan to be countercyclical, but he found little or no cyclical pattern for U.S. and French real wages.

5/ This view seems to be widely recognized as a stylized fact, though its documentation is more difficult. The old implicit contract models feature fixed real wages as one of their major contributions. Taylor (1980) asserts that there is not enough real wage variation in the U.S. for the Gray-Fischer contract model to explain the data; he constructed his own contract model with this fact in mind.

6/ The implicit contract models of Azariadis (1975) and Baily (1974) both incorporate this assumption, as does the asymmetric-information model of Calvo and Phelps (1977). Many of the more recent models of contracting under asymmetric information do not; see for example the special supplement of the Quarterly Journal of Economics (1983). As Chari (1983) points out, the assumption has important implications for when there will be too little employment in bad states of nature.

7/ Most contracting models eschew the interesting aspects of search.

8/ Necessary and sufficient conditions for an interior solution are

(i) $\theta_2 f'(1) < J$

(ii) $U'[U^{-1}(K)] > \lambda/(1-\lambda)$

(iii) $\theta_1 f[f'^{-1}(J/\theta_1)] > U'^{-1}[\lambda/(1-\lambda)]f'^{-1}(J/\theta_1)$

(iv) $J \equiv U'^{-1}[\lambda/(1-\lambda)] - (1-\lambda)/\lambda U\{U'^{-1}[\lambda/(1-\lambda)] - K\}$

9/ See, for example, Harris and Townsend (1981).

10/ See also Radner (1981).

11/ See Gray (1978) and Canzoneri (1980).

12/ Both constraints cannot hold with equality because this would imply $n(\theta_1,p) = n(\theta_2,p)$, which is inconsistent with the first-order conditions which follow.

13/ Phelps and Calvo (1977) conjectured just the opposite, but their basic point is correct; with asymmetric information, the real wage is not fixed.

14/ See for example, Hart (1983).

15/ If we use the quadratic production function $y = \theta n - hn^2$ where $h > 0$, then the wage and employment rules are unambiguously strictly decreasing functions of p. Sargent (1979) uses this production function.

16/ We would like to include the island paradigm here, but we are not sure what to take as the representative model of wage determination. One might simply identify the "local" price with the nominal wage, in which case the real wage would move procyclically. However this procedure is inconsistent with the notion that the real wage is the relative price in a two good --labor and output-- model. Sargent's (1979, ch. 8, section 4) model may be preferable for such a comparison.

17/ The nominal wage may also be indexed in the way described by Gray (1976) without affecting the basic discussion to follow.

18/ See for example Canzoneri (1980) or Canzoneri, Henderson, and Rogoff (1983).

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