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One of the basic regularities of economic exchange is that many trades are governed by contracts that pre–specify a nominal payment to be made for goods or labor services. In particular, such contracts specify dollar (or analogous accounting unit) payments that are not contingent on intervening events. These nominal contracts have been widely viewed as playing a central role in determining aggregate economic behavior. It has also been argued for some time that various roles for monetary policy hinge on the manner in which nominal contracts are written and executed.[1]

Despite the apparent importance of such contracting practices, however, relatively little effort has been devoted to explaining them.[2] This may be because of a general acceptance of the following oral tradition, which is fairly explicit in Fama (1983) or White (1984). In particular, it economizes on calculations to have all prices expressed in a unit of account which is also a medium of exchange, and to write contracts expressed in these same units (that is, to write unindexed contracts). However, this explanation cannot account for the full range of nominal contracts observed in practice. Specifically, consider the following types of contracts, known as "barter contracts", which were common in the eighteenth century American colonies. In a barter contract person A purchases a unit of commodity x on credit from person B. A agrees to deliver some quantity of commodity y to B at some future date, so that money appears on neither side of the transaction. Nevertheless, A would deliver enough of good y so that its nominal value would be at some pre–specified level. Thus in barter contracts it was not the case that money was used in the relevant transactions. Nor was it the case that nominal contracts simplified calculations.[3] Hence a more complete explanation of nominal contracting is required.

This paper presents a setting in which agents may choose to write nominal contracts, completely indexed contracts,[4] or any intermediate type of contract. Moreover, the only risk to which agents are exposed is price–level risk. Nevertheless, some subset of agents will, for a fairly broad class of economies, choose to sell their labor for a pre–specified nominal wage.

This result is obtained by considering an economy in which workers differ in terms of their productive abilities, and are privately informed about their own "types". In this setting there are several devices firms can employ in order to induce self–selection of workers according to their productivities. One such device would involve all firms offering fully indexed contracts and restricting the employment levels of some workers at the equilibrium wage rate. This would amount to using hours restrictions as a sorting device. Another self–selection mechanism would have some firms offering workers fully indexed contracts, while other firms offer only nominal (unindexed) contracts. Under this mechanism a willingness to accept some exposure to price level risk would constitute a signal of type. For some economies the latter is the dominant sorting mechanism. In fact, in certain special cases it permits a first–best allocation of resources to be attained. Moreover, this is the case even though money need never appear in any transactions between employers and employees.

More generally, hours restrictions and incompletely indexed contracts will be employed simultaneously as sorting devices by firms. In this case the model can be used to illustrate the following possibility. If all contracts were (artificially) required to be fully indexed, there would be unemployed labor, but no Phillips curve. When nominal contracts are introduced a Phillips curve is obtained. It is also the case that unemployment is reduced in at least some states of nature. Moreover, the Phillips curve relation obtained has some empirically reasonable properties. For instance, variation in the money supply precedes in time much of the variation it produces in output.[5]

Since nominal contracts function as a sorting mechanism only if there is sufficient variation in the price level, the model also generates a role for rules governing the evolution of the money supply that are not constant growth rate rules. However, the model does not suggest that it is possible for policy makers to "exploit" the Phillips curve relation that arises. In particular, attempts to vary the money supply need produce no contemporaneous effects on output or employment. Moreover, unanticipated changes in the money supply will typically have undesirable consequences for resource allocations.

The format of the paper is as follows. Section I outlines a "real version" of the model in which the price level is constant over time. Thus the use of indexed versus unindexed contracts is a matter of indifference. Section II allows for a random price level. It illustrates that, for a special class of preferences, the use of nominal contracts can eliminate the unemployment that firms use as a sorting device in Section I. It is also possible for the first–best (under full information) allocation of resources to be obtained using such contracts. Section III illustrates by example how the model works under more general preference specifications, and shows how the model can give rise to a Phillips curve with some empirically reasonable properties. Section IV comments on several features of the model specification. It also undertakes some discussion of several questions that arise naturally as the analysis proceeds. The most obvious such question is as follows. The reason why nominal contracts function as a sorting mechanism in the model is that they provide a device for randomizing the consumption streams of parties to the contracts. Since any number of such randomizing devices can be imagined, is there any reason to focus particularly on incompletely indexed contracts? Some possible answers to this question are offered in Section IV. Section V concludes.

I. <u>The Model With a Constant Price Level</u>

In order to illustrate the role that nominal contracts can play in this economy, it is convenient to begin with a setting where the price level is constant. This provides a benchmark for future comparison. Also, in order to understand how nominal contracting functions as a sorting mechanism, it is necessary to produce a monetary economy with heterogeneous, privately informed workers. A simple model is now presented containing all of these features.

The economy is an infinite horizon one, with time indexed by t=0,1,... It consists of a sequence of two period lived, overlapping generations. Each generation is identical in size and composition, and contains four sets of agents. First, there is a group of entrepreneurs, or firms, each of whom is endowed with access to a technology for converting labor into a single consumption good. There is also a set of workers. Workers are divided into two types, indexed by $i \in \{1,2\}$. Production of the good is governed by a (nonstochastic) constant returns to scale technology, so that one unit of type i labor produces π_i units of the consumption good, with $\pi_1 > \pi_2$. In order to fix ideas, there is a fixed, countable set of firms and a continuum of workers.[6] The fraction of workers with i=1 is $\theta \in (0,1)$. Finally, there is a fourth group of agents, who are described below.

Preferences and endowments of agents are as follows. Firms are risk neutral profit maximizers. Firm owners also have some endowment of the good when old, about which more will be said below.

Workers are endowed with one unit of labor when old, to be allocated between work and leisure. Workers do not work when young. Rather in their first period of life firms and workers meet to write contracts governing their old age behavior. Also, for the present workers have no endowment of the consumption good at any date. Finally, letting L_i denote the labor supply of an (old) type i worker, and C_{ij} the consumption of a type i worker at age j, type i agents have preferences described by the utility function $U_i(C_{i2}, 1-L_i)$. (Thus the first period is purely a contracting period; firms and workers undertake no other activity at this time.) The functions U_i are assumed to be strictly increasing in each argument, twice continuously differentiable, and concave.

The remaining set of agents will be referred to as type 3 agents. Type 3 agents have an endowment of one unit of the good when young, and none when old. These agents also do not sell labor. Their preferences are denoted by $U_3(C_{31},C_{32})$, where U_3 is non–decreasing in each argument, twice continuously differentiable, and concave. Type 3 agents are present in the model in order to insure a positive demand for money. Let μ denote the measure of type 3 agents.

There are three items traded in this economy; the single consumption good, labor and fiat money. For the remainder of this section money is supplied in the constant aggregate amount $M > 0$. At t=0 this money stock is held as an endowment by the initial old. No other agents have any endowment of fiat money. Finally, the consumption good is the numeraire at each date. The real wage rate paid to type i workers is denoted by w_i (which need not be indexed by t), and money trades for consumption goods at the rate S_t at t. (Thus S_t is the time t inverse price level.) When possible the subscript is omitted. Also, the focus is on equilibria with $S_t > 0\ \forall t$.

A. Equilibrium

It is assumed that firms are Nash competitors in labor markets. So long as S (the inverse price level) is constant through time, there is no loss of generality in viewing firms as offering contracts to workers of type i consisting of a wage rate w_i, and an hours level L_i. Thus a contract is a pair (w_i, L_i).[7] However, the type of each worker is private information, ex ante. Thus firms can adopt either of two strategies in announcing contracts. They can either announce distinct contracts $(w_1,L_1) \neq (w_2,L_2)$, hoping to induce self–selection of workers by contract accepted, or they can announce a single pooling contract. In either case the contract announcements of firms must be incentive compatible, or in other words, must satisfy the self–selection conditions

(1) $U_1(w_1L_1, 1-L_1) \geq U_1(w_2L_2, 1-L_2)$

(2) $U_2(w_2L_2, 1-L_2) \geq U_2(w_1L_1, 1-L_1)$.

Obviously a pooling contract (that sets $(w_1,L_1) = (w_2,L_2)$) satisfies (1) and (2) trivially.

In addition, it is convenient (although not necessary to the analysis) to impose the restriction on contracts employed by Rothschild and Stiglitz (1976) and Wilson (1977). In particular, it is required that each announced contract earn non–negative profits given the workers accepting it. Thus if $(w_1,L_1) \neq (w_2,L_2)$,

(3a) $w_i \leq \pi_i$; $i = 1,2$

must hold. A pooling contract specifying the common wage rate w must have

(3b) $w \leq \theta\pi_1 + (1-\theta)\pi_2$

that is, it must at least break even if it attracts workers in their population proportions.

A (stationary) Nash equilibrium for this economy is a set of announced contracts (w^*_i,L^*_i); $i = 1,2$, satisfying (1) – (3), and a constant sequence $\{S_t\}$ such that (a) no firm has an incentive to alter its announced contracts, with any announcements subject to (1) – (3), and (b) the money market clears, i.e.,

(4) $\mu\tilde{\psi}(S_{t+1}/S_t) = S_t M \; \forall \; t \geq 0,$

where $\tilde{\psi}(-)$ is the savings function of type 3 agents.

The qualitative features of any equilibrium for the constant value $S = \mu\tilde{\psi}(1)/M$ are identical to those described by Rothschild and Stiglitz (1976). First, no equilibrium in pure strategies need exist. However, parameter values can be chosen so that existence is guaranteed. Second, equilibria need not be Pareto optimal. Third if,

$$\frac{\dfrac{\partial U_1(C,1-L)}{\partial C}}{\dfrac{\partial U_1(C,1-L)}{\partial(1-L)}} \gtrless \frac{\dfrac{\partial U_2(C,1-L)}{\partial C}}{\dfrac{\partial U_2(C,1-L)}{\partial(1-L)}}$$

$\forall \; (C,1-L) \in [0,\pi_1] \times [0,1]$, then any equilibrium displays self–selection of workers, i.e., $(w^*_1,L^*_1) \neq (w^*_2,L^*_2)$. (The proof of this assertion exactly parallels the argument given in Rothschild–Stiglitz (1976), and is omitted here.) Finally, in light of (3), the fact that self–selection occurs, and competition among firms for workers, $w_i = \pi_i$; i = 1,2.

It is straightforward to display diagrammatically the determination of equilibrium values (w_i^*, L_i^*). In Figure 1, then, consumption and hours worked appear on the vertical and horizontal axes, respectively. The loci labelled $C = \pi_i L$ are the zero–profit loci for wage–hours packages which are taken by type i and only type i workers. In light of (3) and the result that self–selection must occur, obviously $w_i = \pi_i$ in equilibrium. It is then easy to verify that equilibrium hours levels are obtained as follows. The self–selection condition (1) cannot bind on the determination of L_2 in equilibrium. Thus L_2^*, the equilibrium hours level of type 2 agents, must occur at a tangency of the locus $C = \pi_2 L$ with an indifference curve for type 2 agents (labelled $\bar{U}_2$ in the figure). $(w_1^* L_1^*, L_1^*)$ must lie on or below the locus $C = \pi_1 L$ and in order to satisfy 2, $(w_1^* L_1^*, L_1^*)$ must lie on or below $\bar{U}_2$. Competition among firms for workers will then imply that $(w_1^* L_1^*, L_1^*)$ must be maximal for type 1 workers among all contracts satisfying these conditions. In figure 1 the most preferred such contract for type 1 workers occurs at point B, implying an equilibrium hours level of L_1^*. In the absence of the self–selection constraint (2), of course, type 1 agents would obtain a contract specifying the wage rate π_1 and the hours level $\tilde{L}_1 > L_1^*$, so for the preferences depicted in figure 1, type 1 agents will experience unemployment (or underemployment).[8]

In general, not enough assumptions have been made to guarantee that (2) will be binding in equilibrium. If it is not then the (stationary) Nash equilibria for this economy coincide with the stationary competitive equilibria for the full information version of the economy. If (2) is binding then an equilibrium may or may not exist. Existence can be guaranteed by an appropriate choice of θ, however, as in Rothschild and Stiglitz (1976).

II. Nominal Contracts

When the (inverse) price level is constant, it is a matter of indifference whether contracts specify real or nominal wage payments. This is not the case when the money supply is stochastic, however. Let $E = \{1,2\}$ denote the set of possible states, corresponding to different realizations of the money supply. Let e denote a typical element of E. Then there are two possible realizations of the money supply at each date, denoted M(e). Realizations of the money supply are independent and identically distributed across periods. Let p be the probability that e=1 at any date. Finally, let $M(1) \equiv M$ and $M(2) \equiv qM$; $0 < q < 1$.

The remaining notation required is as follows. S(e) is the inverse price level in state e, and $L_i(e)$ is the quantity of labor a young type i agent contracts to deliver next period if the current state is e. If e' denotes "next period's state," contracts specifying a labor supply schedule $L_i(e,e')$ contingent on next period's state are ruled out. This permits considerable simplification without affecting the basic argument. Modifications required if $L_i(e,e')$ is allowed to depend non–trivially on e' are discussed below. Finally, the consumption of an old type i worker experiencing the sequence of states (e,e') is denoted by $C_{i2}(e,e')$.

All agents have von–Neuman–Morgenstern preferences. The current state of the world is common knowledge at each date, and as is implicit in the notation, attention is restricted to stationary equilibria. It is assumed that all monetary changes are accomplished via proportional transfers to old type 3 agents. Let $\psi(-)$ denote the savings function of these agents, which depends in general on S(1)/S(e), S(2)/S(e), and p for a young agent born in state e. Finally, for simplicity, trading in state contingent claims is ruled out.

A. Equilibrium

As before, firms are imperfect Nash competitors in labor markets. However, now it will generally matter whether wage payments are specified in real or nominal terms (or are partially indexed). Formally, a contract is a four–tuple $[x_i, w_i, \lambda_i, L_i(e)]$. Loosely speaking, w_i denotes the number of goods to be delivered to a worker per unit of labor supplied, while x_i denotes the number of dollars (or goods of equivalent dollar value) to be delivered per unit worked. λ_i is a scalar satisfying $\lambda_i \in [0,1]$. The *ex post* real wage specified by a contract is denoted $z_i(e')$ (where e' is "next period's state"), with $z_i(e') = \lambda_i S(e')x_i + (1-\lambda_i)w_i$. Thus λ_i represents the degree of (non) indexation of a contract. $\lambda_i = 0$ represents complete indexation, for instance. And finally, of course, $L_i(e)$ specifies an hours level as a function of the state at the time of contracting.

In order to retain comparability with the previous section, an analogue of assumption (3) is imposed. Then if type 1 and 2 agents are distinguishable (i.e., self–select according to contracts accepted), the ex post real wage rates $z_i(e)$ are required to satisfy

(5a) $pz_i(1) + (1-p)z_i(2) \leq \pi_i$; $i=1,2$.

If these agents are not distinguishable, then the common ex post wage rates $z(e)$ must satisfy

(5b) $pz(1) + (1-p)z(2) \leq \theta\pi_1 + (1-\theta)\pi_2$.

Hence, as before, each individual contract offered must at least break even in expected terms, given the workers accepting it.[9]

It is also the case that announced contracts must be incentive compatible. This requires that they satisfy

(6) $$pU_1[\lambda_1 S(1)x_1L_1(e)+(1-\lambda_1)w_1L_1(e),1-L_1(e)] + (1-p)U_1[\lambda_1 S(2)x_1L_1(e) + (1-\lambda_1)w_1L_1(e),1-L_1(e)] \geq pU_1[\lambda_2 S(1)x_2L_2(e) + (1-\lambda_2)w_2L_2(e),1-L_2(e)] + (1-p)U_1[\lambda_2 S(2)x_2L_2(e) + (1-\lambda_2)w_2L_2(e),1-L_2(e)];\ e = 1,2,$$

(7) $$pU_2[\lambda_2 S(1)x_2L_2(e)+(1-\lambda_2)w_2L_2(e),1-L_2(e)] + (1-p)U_2[\lambda_2 S(2)x_2L_2(e) + (1-\lambda_2)w_2L_2(e),1-L_2(e)] \geq pU_2[\lambda_1 S(1)x_1L_1(e) + (1-\lambda_1)w_1L_1(e),\ 1-L_1(e)] + (1-p)U_2[\lambda_1 S(2)x_1L_1(e) + (1-\lambda_1)w_1L_1(e),1-L_1(e)];\ e = 1,2.$$

Notice that if $\lambda_i = 0$ ($i=1,2$), then no workers face any risk from inflation and $L_i(1) = L_i(2)\ \forall i$ will hold. Then (6) and (7) reduce to (1) and (2).[10]

A (stationary) Nash equilibrium for this economy is a set of announced contracts satisfying (5) – (7), and a set of values $S(e)$, such that (a) no firm has an incentive to alter its announced contracts, with any new announcements subject to (5) – (7), and (b) the money market clears, i.e.,

$$(8) \qquad \mu\psi\left[\frac{S(1)}{S(e)}, \frac{S(2)}{S(e)}, p\right] = S(e)M(e); \quad e = 1,2.$$

As before, any equilibrium involves self–selection of workers by contract accepted.[11] Given this fact, competition among firms for workers implies that type 2 workers receive the maximal contract for them consistent with (5a), and with the process generating the (inverse) price level.[12] Similarly, type 1 workers receive the maximal contract for them consistent with (5a), with self–selection occurring, and with the process generating the (inverse) price level. Finally, notice that since $L_i(e)$ is contractually pre–specified when young, if $\lambda_i = 1$ for any i then the zero expected profit condition implies that $x_i = \pi_i/ES(e')$ for that i.

As will become apparent, a general analysis of equilibrium contracts in this setting would involve a very large array of possible outcomes. To illustrate how the use of nominal contracts can function as a sorting device, then, the strategy of examining some specific examples is now adopted.

B. An Example Where Nominal Contracting Produces a First Best Allocation

Suppose the measure of type 3 agents is fixed at $\mu = 1$, and suppose that type i agents have the following utility functions:

$$U_1(C,1-L) = \eta C + 1 - L$$

$$U_2(C,1-L) = \ln C + \ln[(1-L)+k]$$

$$U_3(C_{31},C_{32}) = C_{32}.$$

Then an economy in this class is represented by a vector of parameters $(k,\pi_1,\pi_2,\eta,\theta)$ with $\pi_1 > \pi_2 > 0$, $\eta\pi_1 > 1$, $\theta \in (0,1)$, and $k > -1$.

It is useful to begin by analyzing two benchmark cases for purposes of comparison. Therefore an equilibrium for this economy is derived first under full information (with a constant price level), and then under private information with a constant price level. Finally, an economy with stochastic money supply is considered.

1. Full Information: Constant Price Level

Obviously, real versus nominal contracting is a matter of indifference to all. Therefore, set $\lambda_i = 0 \; \forall i$. Then $w_i = \pi_i$, $i = 1,2$. Given these real wages, L_1 solves

$$\max_{0 \leq L_1 \leq 1} \quad (\eta\pi_1 - 1)L_1.$$

Since $\eta\pi_1 > 1$, $L_1 = 1$. Also, L_2 solves

$$\max_{0 \leq L_2 \leq 1} \quad \ln \pi_2 L_2 + \ln(1+k-L_2).$$

An interior optimum involves setting $L_2 = \frac{1+k}{2}$. (Clearly, the existence of an interior optimum requires $-1 < k \leq 1$.) Finally, type 3 agents save their entire endowment when young. Hence, $\psi(-) = 1$. Utility levels, then, are as follows.

$$U_1 = (\eta\pi_1 - 1)L_1 + 1 = \eta\pi_1$$

$$U_2 = \ln\left[\pi_2\left[\frac{1+k}{2}\right]^2\right]$$

$$U_3 = 1.$$

As this is a standard steady state competitive equilibrium with valued fiat money, the above is a first–best allocation of resources.

2. Private Information: Constant Price Level

As a second benchmark, it is useful to consider what happens when nominal contracting cannot alter resource allocations (as when the price level is constant). Also, obviously, private information does not change matters unless (2) is violated by the equilibrium just derived. The full–information allocation is <u>not</u> incentive compatible iff

(9) $\quad \ell n\pi_1 + \ell nk > \ell n\left[\pi_2\left[\frac{1+k}{2}\right]^2\right],$

or equivalently, iff

(9′) $\quad k > \left[\frac{\pi_2}{\pi_1}\right]\left[\frac{1+k}{2}\right]^2.$

(9′) is henceforth assumed to hold.

This economy, under (9′), is in the situation depicted in Figure 1. The equilibrium hours level of type 2 agents is the same as under full–information, so $L_2^* = \frac{1+k}{2}$. L_1^* is determined by the self–selection condition (2) at equality, along with $w_1 = \pi_1$, i.e. by

(10) $\quad \ell n\left[\pi_2\left[\frac{1+k}{2}\right]^2\right] = \ell n\pi_1 L_1^* + \ell n(1+k-L_1^*).$

(10) can be solved directly for L_1^* to obtain

$$L_1^* = \left[\frac{1+k}{2}\right]\left[1 - \left[\frac{\pi_1-\pi_2}{\pi_1}\right]^{\frac{1}{2}}\right].$$

Finally, the price level is as before. Notice that, by (9′),

$$U_1 = \eta\pi_1 L_1 + (1-L_1) < \eta\pi_1.$$

3. <u>Nominal Contracts</u>

As above, suppose that M(1) = M and M(2) = qM; $0 < q < 1$. It is shown in this section that p and q can be chosen (in fact for any $p \in (0,1)$, q can be chosen) so that a first best allocation of resources is obtained through the use of nominal contracts for type 1 workers.

The argument proceeds in three steps. First, consider the determination of the inverse price level. Since $\psi(-) \equiv 1$,

(11) $S(e)M(e) = 1$; $e = 1,2$.

Therefore $S(1) = 1/M$ and $S(2) = 1/qM$. Then consider the utility of type 3 agents. When young type 3 agents accumulate real balances equal to $S(e)M(e)$. Since monetary injections are accomplished through proportional transfers, the old age real balances of a type 3 agent are $S(e')M(e)$, multiplied by the proportional transfer (which is $M(e')/M(e)$). Hence the net of transfer real balances of an old type 3 agent are $S(e')M(e') = 1$, by (11). Then $U_3 = 1$, as before.

Second, in equilibrium $\lambda_2 = 0$ (type 2 contracts are fully indexed). To see this, it suffices to suppose that $\lambda_2 = 1$, and to show that some firm has an incentive to offer type 2 workers an alternative contract. Then suppose that $\lambda_2 = 1$. In equilibrium firms must earn zero expected profits, so that $x_2 = \pi_2/ES(e')$. Also, it is easy to check that, given these contractual terms, the most preferred hours level for type 2 workers is $L_2(e) = (1+k)/2$ $\forall e$. Then expected consumption for type 2 workers would be

$$E\left[\frac{1+k}{2}\right]\frac{\pi_2}{ES(e')}[S(e')] = \pi_2\left[\frac{1+k}{2}\right].$$

But since type 2 workers are risk averse, clearly some firm can offer these workers a fully indexed contract with $w_2 < \pi_2$ and $L_2(e) = (1+k)/2$, and attract all type 2 workers. Moreover, such a contract would earn positive profits. This contradicts that any equilibrium could have $\lambda_2 = 1$. Thus $\lambda_2 = 0$, and type 2 contracts must have $w_2 = \pi_2$ and $L_2 = (1+k)/2$, as above.

Third, it is shown that p and q can be chosen so that an equilibrium contract for type 1 workers has $L_1(e) = 1$ $\forall e$, and $\lambda_1 = 1$. (Then, of course, $x_1 = \pi_1/ES(e')$.) To show that this is an equilibrium contract, it suffices to show that it is incentive compatible, for appropriate choices of p and q, and that it is the maximal incentive compatible contract for type 1 workers.

To show that this is an incentive compatible contract for appropriate choices of p and q, note that the old period consumption levels of agents taking this contract are $C_{12}(1) = S(1)\pi_1/ES(e')$ and $C_{12}(2) = S(2)\pi_1/ES(e')$. Using $S(1) = 1/M$ and $S(2) = 1/qM$, then,

$$C_{12}(1) = \frac{\pi_1 q}{pq + (1-p)}$$

$$C_{12}(2) = \frac{\pi_1}{pq + (1-p)}$$

A contract specifying these state contingent consumption levels is incentive compatible iff

$$\text{(12)} \qquad p\ell n\left[\frac{\pi_1 q}{pq+(1-p)}\right] + (1-p)\ell n\left[\frac{\pi_1}{pq+(1-p)}\right] + \ell nk \leq \ell n\left[\pi_2\left[\frac{1+k}{2}\right]^2\right].$$

or equivalently iff

$$\text{(12}'\text{)} \qquad \left[\frac{\pi_2}{\pi_1}\right]\left[\frac{1+k}{2}\right]^2 \geq \frac{kq^p}{pq + (1-p)}.$$

Now by (9′)

$$\lim_{\substack{q\to 1\\ q<1}} \frac{kq^p}{pq + (1-p)} > \left[\frac{\pi_2}{\pi_1}\right]\left[\frac{1+k}{2}\right]^2.$$

Also, clearly

$$\lim_{\substack{q\to 0\\ q>0}} \frac{kq^p}{pq + (1-p)} = 0 < \left[\frac{\pi_2}{\pi_1}\right]\left[\frac{1+k}{2}\right]^2.$$

Hence, by the intermediate value theorem, for any $p \in (0,1)$ there exists a value $q'(p) \in (0,1)$ such that

$$\left[\frac{\pi_2}{\pi_1}\right]\left[\frac{1+k}{2}\right]^2 = \frac{k(q')^p}{pq' + (1-p)}.$$

Then $\forall\, q \in (0,q'(p)]$, it is incentive compatible to set $L_1(e) = 1\ \forall\, e$.

Finally, consider the expected utility of type 1 workers under the hypothesized contract. This is

$$\eta\left[p\frac{S(1)}{ES(e')} + (1-p)\frac{S(2)}{ES(e')}\right]\pi_1 L_1(e) + [1-L_1(e)] = \eta\pi_1.$$

Then the allocation obtained yields an expected utility level for all agents equal to that obtained under full information. Since the full information allocation is Pareto optimal, the contracts above yield the maximal utility levels for type 1 workers. Thus, for p and q satisfying (12′), setting $\lambda_1 = 1$ and $L_1(e) \equiv 1$ is an equilibrium contract for these agents.

C. Discussion

If p and q are chosen to satisfy (12′), the use of nominal contracts results in an improvement in the welfare of type 1 workers. This welfare improvement occurs precisely because more productive workers in this economy are less risk averse than other workers. Therefore the use of nominal contracts, which produces risk due to the possibility of price level variations, can be used as a sorting mechanism. The empirical plausibility of this kind of sorting mechanism is discussed below.

Several comments are now in order. First, nothing requires that workers governed by nominal contracts be paid in money. The contracts derived above could take the form of the barter contracts discussed in the introduction.

Second, the explanation of nominal contracts as a sorting device could be contrasted with other explanations of the use of nominal contracts based on private information. Azariadis and Cooper (1985) and Cooper (1982) produce models in which private information prevents the existence of complete contingent claims markets. Nominal contracts then arise as a risk sharing device. The Azariadis–Cooper reasoning, however, is contrary to the normal view that nominal contracts expose agents to more risk than indexed contracts. This view is consistent, of course, with the idea that nominal contracts are a risk producing device that aids in inducing self–selection.

Third, for the examples of this section a first best allocation can be attained. In particular, in equilibrium no restrictions on the hours worked by type 1 agents are required to induce self–selection. Neither of these results hold generally. For more general classes of preferences, for instance, incomplete contract indexation and hours restrictions can be used simultaneously to produce self–selection. Also, hours can vary in a manner that produces an empirical Phillips curve. An economy illustrating these features is now examined.

III. Nominal Contracts and the Phillips Curve

The assumption that type 1 workers are risk neutral is now relaxed. Relaxation of this assumption greatly increases the range of possible equilibrium outcomes, however. In fact, the set of such outcomes is sufficiently large that a general analysis would be quite cumbersome. Thus this section restricts its attention to an example with the following features: (a) a Phillips curve with the "proper" slope is observed, (b) hours vary over a "business cycle," and (c) a first best allocation of resources cannot be obtained.

To produce such an example, an additional assumption will be introduced. In particular, firms will not be given the option of offering partially indexed contracts. Thus $\lambda_i \in \{0,1\}$, i = 1,2, is imposed. This assumption permits considerable simplification in the analysis, while allowing the basic points to be illustrated. Also, the assumption that contracts specify hours levels as a function of the young period state alone is retained in this section.

For the remainder of the section, the preferences and endowments of type 2 and 3 agents are the same as previously. The preferences of type 1 workers are[13]

$$U_1(C,1-L) = \eta C - \left[\frac{\alpha}{2}\right]C^2 + (1-L);\ \alpha > 0.$$

Also, it is now assumed that type 1 workers are endowed with one unit of the good when young. This is obviously saved through the acquisition of real balances by these agents. It is assumed that agent's portfolios are not observed by firms.

An equilibrium for this economy is defined as above. Any equilibrium will (generically) display self–selection of workers by contract accepted. Using this fact, a numerical example is now analyzed. As before, several benchmark cases are considered in order to underscore the role played by nominal contracts.

A. An Example

Let $k = 1$, $\pi_1 = 1$, $\pi_2 = \frac{3}{4}$, $\eta = \frac{5}{2}$, $\alpha = \frac{1}{8}$, $p = \frac{1}{4}$, and $q = \frac{1}{10}$ (where $M(2) = qM$ with probability $1-p$). As a first benchmark the equilibrium of this economy under full information and a constant price level ($q=1$) is examined.

1. Full Information: Constant (Inverse) Price Level

As before, $L_2 = (1+k)/2 = 1$, and $U_2 = \ln[\pi_2(1+k)^2/4] = \ln(\frac{3}{4})$. Also, recall that type 1 workers have one unit of the good when young, which they use to acquire real balances. With $M(1) = M(2)$, the (gross) return on real balances is one. Then the utility of type 1 workers is

$$U_1 = \eta C_{12} - \left[\frac{\alpha}{2}\right] C_{12}^2 + (1-L) = \eta(\pi_1 L_1+1) - \left[\frac{\alpha}{2}\right](\pi_1 L_1+1)^2 + (1-L_1),$$

which is to be maximized by choice of L_1. This results in setting $L_1 = 1$, and $U_1 = \eta(\pi_1 + 1) - (\alpha/2)(\pi_1 + 1)^2 = \frac{19}{4}$.

2. Private Information: Constant (Inverse) Price Level

As a second benchmark, the equilibrium under private information and a constant price level can be computed. It is easy to check that the full information equilibrium just derived violates equation (2). Then Figure 1 depicts the determination of an equilibrium under a constant price level. It is straightforward to verify that the equilibrium that emerges is identical to that under private information and a constant price level derived in the example of section II. Then $L_1 = \frac{1}{2}$ (as given by equation (10)), and $U_1 = \eta(\pi_1 L_1 + 1) - (\alpha/2)(\pi_1 L_1 + 1)^2 + (1-L_1) = 4.109$.

3. Full Information: Variable Price Level

A third benchmark is the case of full information under a stochastic money supply. It is necessary to compute the equilibrium in this case in order to verify that the incentive constraints bind on the determination of equilibrium contracts.

Under full information all agents will receive indexed contracts. Then $L_2(e) = (1+k)/2 = 1$. A young type 1 worker negotiating a contract in state e faces the equilibrium real wage rate $w_1 = \pi_1$. Then competition among firms for workers will imply that $L_1(e)$ solves the problem

$$\max_{0 \leq L_1(e) \leq 1} \eta\left[\pi_1 L_1(e) + \frac{ES(e')}{S(e)}\right] + [1-L_1(e)] - p\left[\frac{\alpha}{2}\right]\left[\pi_1 L_1(e) + \frac{S(1)}{S(e)}\right]^2$$
$$-(1-p)\left[\frac{\alpha}{2}\right]\left[\pi_1 L_1(e) + \frac{S(2)}{S(e)}\right]^2; \; e = 1,2.$$

For the parameter values of the example, the solution sets $L_1(1) = L_1(2) = 1$. Then, as above, the equilibrium contracts under full information violate the self–selection constraints.

4. Private Information: Variable Price Level[14]

As before, $\lambda_2 = 0$ in equilibrium. Then $w_2 = \pi_2$, $L_2 = (1+k)/2 = 1$, and $U_2 = \ln(\frac{3}{4})$.

With respect to type 1 contracts, there are two possibilities for each young period state e. The first is that $\lambda_1 = 0$ (full indexation). Then the remainder of the contractual terms for type 1 workers are determined in the same way as when there is no price level uncertainty. Thus $w_1 = \pi_1$ and $L_1(e) = \frac{1}{2}$ would hold for each state where type 1 contracts were indexed.

The second possibility is that $\lambda_1 = 1$ (nominal contracts). In this case $x_1 = \pi_1/ES(e')$, and the most preferred hours level for type 1 workers (which need not be incentive compatible) is obtained by solving the problem

$$\text{(P)} \qquad \max_{0 \leq L_1(e) \leq 1} \left\{ p\eta \left[\frac{\pi_1 S(1)}{ES(e')}\right] + (1-p)\eta \left[\frac{\pi_1 S(2)}{ES(e')}\right] \right\} L_1(e) + [1-L_1(e)] + \eta \frac{ES(e')}{S(e)}$$

$$-p\left[\frac{\alpha}{2}\right]\left[\frac{\pi_1 S(1)}{ES(e')} L_1(e) + \frac{S(1)}{S(e)}\right]^2 - (1-p)\left[\frac{\alpha}{2}\right]\left[\frac{\pi_2 S(2)}{ES(e')} L_1(e) + \frac{S(2)}{S(e)}\right]^2; \ e = 1,2.$$

In order to determine which option is employed in each young period state, it is useful to begin by considering the determination of the (inverse) price level. The demand for real balances at each date consists of young type 1 and 3 agents supplying their (fixed) young period endowments in exchange for currency. Let y denote the aggregate young period endowment of these agents. Then $S(e)M(e) = y \ \forall e$, so $S(1) = y/M$ and $S(2) = y/qM$. Thus, as previously,

$$\frac{S(1)}{ES(e')} = \frac{q}{pq + (1-p)} = \frac{4}{31}$$

$$\frac{S(2)}{ES(e')} = \frac{1}{pq + (1-p)} = \frac{40}{31}.$$

Parenthetically, it will be recalled that all monetary transfers are made to old type 3 agents. It might be noted that, depending on the relative sizes of the type 1 and 3 agent populations, feasibility of this transfer scheme may require that old type 3 agents have some endowment of the consumption good when old. It can be assumed that type 3 agents have whatever old period endowment is necessary, as this does not affect any of the analysis.

There are now two cases to consider with respect to type 1 contracts.

<u>Case 1: e = 1</u>. Suppose that $\lambda_1 = 1$. Then the solution to the problem (P) is to set $L_1(1) = 1$. The expected utility of type 1 workers under this contract is 15.88. If, on the other hand, $\lambda_1 = 0$, then $L_1(1) = \frac{1}{2}$. The expected utility level associated with this contract is

$$\eta\left[\pi_1 L_1(1) + \frac{ES(e')}{S(e)}\right] + [1-L_1(1)] - p\left[\frac{\alpha}{2}\right][\pi_1 L_1(1) + 1]^2$$

$$-(1-p)\left[\frac{\alpha}{2}\right]\left[\pi_1 L_1(1) + \frac{S(2)}{S(1)}\right]^2 = 15.923.$$

Thus a contract with $\lambda_1 = 0$ and $L_1(1) = \frac{1}{2}$ is preferred to any nominal contract by type 1 workers. Since the contract $\lambda_1 = 0$, $w_1 = \pi_1$, $L_1(1) = \frac{1}{2}$ is incentive compatible, this is the equilibrium contract when e = 1. Notice that, at the wage rate $w_1 = \pi_1$, type 1 workers would like to set $L_1(1) = 1$. Therefore the equilibrium contract involves unemployment (or underemployment) of type 1 workers.

Case 2: e = 2. Suppose that $\lambda_1 = 1$, so that $x_1 = \pi_1/ES(e')$. Then the solution to (P) is to set $L_1(2) = 1$. It is straightforward to verify that, with $L_1(2) = 1$, (7) collapses to (12′). For the parameters of the example, (12′) is satisfied.[15] It is also necessary to check that (6) is satisfied. The maximized value of the objective in (P), given e=2, is 4.19. A type 1 worker taking a type 2 contract would receive the (indexed) real wage $w_2 = \pi_2 = \frac{3}{4}$, and would work one unit. This would result in an expected utility level of

$$\eta\left[\pi_2 L_2 + \frac{ES(e')}{S(2)}\right] + (1-L_2) - p\left[\frac{\alpha}{2}\right]\left[\pi_2 L_2 + \frac{S(1)}{S(2)}\right]^2 - (1-p)\left[\frac{\alpha}{2}\right][\pi_2 L_2 + 1]^2 = 3.658.$$

Thus (6) is satisfied as well.

It remains to consider the possibility that $\lambda_1 = 0$. As before, in this case $w_1 = \pi_1 = 1$, and $L_1(2) = \frac{1}{2}$. This contract yields an expected utility level for type 1 workers given by

$$\eta\left[\frac{1}{2} + \frac{ES(e')}{S(2)}\right] + \frac{1}{2} - p\left[\frac{\alpha}{2}\right]\left[\frac{1}{2} + \frac{S(1)}{S(2)}\right]^2 - (1-p)\left[\frac{\alpha}{2}\right]\left[\frac{1}{2} + 1\right]^2 = 3.578.$$

Thus the most preferred contract for type 1 workers is the nominal contract, which will be the equilibrium outcome when e = 2.

B. The Phillips Curve

When the time t state is e = 1, the time t price level is high (or in other words, $S(1) < S(2)$, so the inverse price level is low). Then between t and t+1 the price level will be expected to fall, or on average there will be deflation. Also at time t $L_1(1) = \frac{1}{2} < L_1(2)$ will be the contractually pre–specified level of hours to be worked by type 1 agents at t+1. Since $L_2(1) = L_2(2)$, on average deflation will accompany low employment and output levels. Therefore a Phillips curve will be observed.

In certain respects the Phillips curve generated by this economy will have some empirically reasonable features. First, since hours worked at t+1 are determined at t, movements in the money stock will tend to occur before movements in output and employment. This is a widely noted empirical regularity [Friedman and Schwartz (1963), King and Plosser (1984), Prescott (1983)]. Second, since time t+1 hours are determined by the realization of time t money supply (which is distributed independently across periods), the time t+1 money supply and the time t+1 level of output are uncorrelated. This is consistent with the observations of King and Plosser (1984) on the low contemporaneous correlation between output and the money stock. The same feature of the model avoids the implication that the price level is counter–cyclical, which would be contrary to observation [Prescott (1983)].

Several other features of the example are worthy of note as well. First, relative to the situation under a constant price level, the use of nominal contracts (with a stochastic money supply) reduces the level of unemployment in at least some states of the world. This is the case even though a Phillips curve emerges.

Second, the example produces a situation that an outside observer might incorrectly interpret as "endogenous indexation" or "endogenous contract length". In particular, if the time t state is e=1 the price level will be high, and all new contracts will be indexed. An outside observer might be led to attribute this indexation (which is not observed when e=2 and prices are low) to the current high level of prices (which would "alert" workers to the potential costs of not indexing wages). Since having fully indexed contracts is equivalent to choosing to operate in spot auction markets, high price levels could also be associated with contracts of (arbitrarily) short length. Such an interpretation of events would, of course, not be warranted.

IV. Discussion

Several aspects of the preceding analysis merit comment. First, it is natural to ask how the analysis would be altered if contracts written in (the young period) state e specified a schedule $L_i(e,e')$ of hours levels contingent on next period's state realization. Suppose, for the sake of simplicity, that $\lambda_i \in \{0,1\}$ is imposed, as in section III. Then if $\lambda_1 = 1$ held, x_1, $L_1(e,1)$, and $L_1(e,2)$ would have to be set so as to satisfy the zero profit condition

$$(13) \quad p[\pi_1 - S(1)x_1]L_1(e,1) + (1-p)[\pi_1 - S(2)x_1]L_1(e,2) = 0; \; e = 1,2.$$

In addition, since $\lambda_2 = 0$ would continue to hold, type 1 contracts would have to satisfy the self–selection condition

$$(14) \quad pU_2[S(1)x_1L_1(e,1),1-L_1(e,1)] + (1-p)U_2[S(2)x_1L_1(e,2),1-L_1(e,2)] \leq U_2(\pi_2L_2,1-L_2); \; e = 1,2.$$

Then competition among firms for workers would imply that x_1, $L_1(e,1)$, and $L_1(e,2)$ would be chosen to maximize

$$pU_1[S(1)x_1L_1(e,1),1-L_1(e,1)] + (1-p)U_1[S(2)x_1L_1(e,2),1-L_1(e,2)]; \; e = 1,2,$$

subject to (13), (14), and $0 \leq L_1(e,e') \leq 1$, where for simplicity it has been assumed that type 1 workers have no endowment of the good when young.

Even with $\lambda_1 \in \{0,1\}$ imposed, this is a fairly messy optimization problem. Unless the solution happens to have $L_1(e,1) = L_1(e,2)$ (in which case the previous analysis applies) a closed form solution will not be available if $U_2(-)$ is strictly concave. Thus, for the illustrative purposes of this paper, it is desirable to have contracts specify hours levels that depend only on the young period state.

Second, nominal contracts function as a sorting mechanism because contracts specifying incompletely indexed wage payments allow price level variation to induce variance in the consumption levels of type 1 workers. This suggests, in turn, that type 1 workers must be less risk averse than type 2 workers in order for nominal contracts to play this role. Such a conclusion would be incorrect, however. Smith (1985) produces a version of the economy studied above in which agents are three period lived, and in which all agents have linear utility functions. Nevertheless, in the presence of some randomness in the money supply, nominal contracts can still be used as a sorting device. This possibility arises because differences in patterns of asset holdings among agents cause them to act as if they had different attitudes towards price level risk. This is sufficient to allow nominal contracts to be used as a sorting device.

Third, the use of nominal contracts to induce self–selection relies on the government producing sufficient randomness in the price level. It is natural to ask whether the parties to a given contract could not produce sufficient randomness in consumption allocations through the use of their own randomizing devices? This question leads to three comments. (a) If the use of a privately controlled randomized payments scheme produces profits for one party to the contract under particular realizations, this produces incentives to "cheat". This makes it natural to use a randomizing device that is not manipulable by parties to the contract. Aggregate random variables, such as the price level, would be one candidate. Of course other random, generally observable objects (such as sunspots) could also be used for this purpose.

(b) Incentives to "cheat" could be avoided if the ex post real wage rate was always π_1. But then in the example economy of section II, for instance, the realized hours level $L_1(e)$ would have to satisfy $L_1(e) < 1$ for some event e occurring with positive probability. Then a first best allocation of resources could not be achieved.

(c) It is possible to produce examples with the following feature. Any equilibrium randomizing device results in the expected values of all endogenous variables being equal to their expected values under nominal contracts. [See Smith (1985).] Thus, in expected value terms, any randomizing scheme replicates the outcome obtained through the use of nominal contracts. Moreover, such examples can be constructed with all agents being risk neutral. Therefore, all randomizing devices simply replicate the (expected) utility levels obtained under nominal contracting as well.

V. Conclusions

In certain respects the analysis here retains the flavor of many earlier models of nominal contracts. The assumption that firms compete for labor services implies that nominal wages are set so as to equate expected real wages to some "target level" (marginal product) as in Fischer (1977a). Also, the contracts obtained by type 1 workers depend critically on the contracts of type 2 workers. This is similar in spirit to the model of Taylor (1980), where comparisons among agents covered by different contracts are used in specifying equilibrium wage rates. However, all nominal wage rates are set one period in advance, as in Gertler (1982). Finally, the analysis follows the suggestion of Fischer (1977b) that informational asymmetries create a role for contractual rigidities.

However, in contrast to conventional wisdom, for some classes of economies (such as the example of section II) nominal contracting, in conjunction with an appropriately variable money supply, can result in a first best allocation of resources. This is true even though nominal contracts enhance the risk faced by all parties to the contract (contrast with Azariadis–Cooper (1985) and Cooper (1982)). Also, nominal contracts do not arise because they simplify calculations, or because money is used in all transactions. In fact, the model can easily explain the existence of the unindexed barter contracts discussed in the introduction.

As in the example of section III, the (endogenous) use of nominal contracts can give rise to a Phillips curve. Such a Phillips curve would not be observed in a pure spot market ($\lambda_i = 0$) version of the economy, since in such an economy employment would be constant over time. Once nominal contracts are admitted an empirical Phillips curve emerges. However, for the particular values of p and q, the use of nominal contracts raises hours and output levels in some states, and does not reduce employment or output in any state.

It remains to say something about the empirical plausibility of firms using indexed versus unindexed wage contracts as a sorting mechanism. The only testable empirical implication of the analysis appears to be that type 1 workers (high average wage earners) should receive incompletely indexed contracts, while type 2 workers receive fully indexed contracts. There appears to be some loose empirical support for this implication of the model. First, the one industry where cost–of–living adjustments are virtually non–existent is the (high wage) construction industry. Second, Wilton (1980), in an examination of pre–1976 Canadian contracts, shows that among contracts with cost–of–living escalator clauses, high wage workers receive less inflation protection than low wage workers. This suggests at least a certain amount of support for the analysis.

Notes

1. On the first point see Fischer (1977a,b, 1984), Gertler (1981, 1982), or Taylor (1980). On the second see, e.g., Simons (1948) or Mints (1950).
2. Exceptions are Azariadis and Cooper (1985) and Cooper (1982).
3. As an additional point of note, the use of barter contracts was widespread both in Pennsylvania, which had a relatively stable price level, and in Massachusetts, which did not. Barter contracts are discussed in some detail by Baxter (1945).
4. The use of indexed contracts below is equivalent to choosing to operate in spot (auction) markets.
5. See, e.g., Friedman and Schwartz (1963) or King and Plosser (1984) for evidence on this point.
6. Under this assumption each individual worker's contribution to the output of a firm is negligible.
7. It is assumed that firms are not allowed to offer contracts consisting of lotteries, and that firms are precluded from the use of mixed strategies. The first of these assumptions is discussed further in Section IV.
8. It may appear odd to have only high productivity workers experience unemployment. However, as noted below, incentive compatibility constraints need not bind between adjacent types of workers. Thus it would be possible to have three or more types of workers, with unemployment confined to the "next to lowest type" in terms of productivity. For simplicity, however, the two type representation of the text is retained throughout.
9. Notice that $z_i(e) \leq \pi_i$ need not hold. If $z_i(e) > \pi_i$ for some e, then entrepreneurs will need to have a positive endowment of the good when old to meet payrolls. Since the endowments of entrepreneurs do not enter the analysis, it can be assumed that their endowments are as large as necessary to meet their payroll obligations.

10. It will be noted that, as before, firms do not employ mixed strategies or directly introduce contracts consisting of lotteries.

11. To see this, notice that if self–selection did not occur an equilibrium would necessarily involve firms offering fully indexed pooling contracts. The Rothschild–Stiglitz (1976) argument as to why this cannot occur would then apply immediately.

12. In particular, (6) cannot bind on the determination of type 2 contracts. This follows from the fact that firms have the option of offering contracts with $\lambda_1 = 0$. Thus, since (1) did not bind in section I, and since the ability to set $\lambda_1 \neq 0$ can only increase the expected utility of type 1 workers, (6) cannot bind here.

13. Parameters will be restricted so that $\frac{\partial U_1}{\partial C} > 0$ holds throughout.

14. Parenthetically, the discussion of this section illustrates why it is desirable to rule out markets in state contingent claims. Two problems with introducing such markets are as follows.

    (i) Clearly type 1 agents would like to insure when young against old age price level variation. Given the parameters of the example, it would not be feasible for type 2 agents to purchase the optimal insurance policy purchased by type 1 agents. Thus, if insurance purchases were publicly observable, the purchase of price level insurance would perfectly signal type. Of course the model could be altered to make such insurance purchases feasible for type 2 agents, say by giving them some endowment of the good in old age. However, the presence of insurance would then complicate the self–selection conditions to an extent that would be quite difficult to deal with. Hence considerations of tractability preclude this approach.

(ii) Alternatively, if insurance purchases were not observable by firms type 2 agents could use insurance markets to partially "undo" the effects of nominal contracts. Thus employers would want to make such insurance purchases observable, perhaps by offering their own insurance to employees. This would, of course, recreate the modelling problems discussed above.

15. Notice that (12′) is satisfied with strict inequality. The simplification obtained by imposing $\lambda_i \in \{0,1\}$ is that, in equilibrium, the incentive constraint (7) need not hold with equality.

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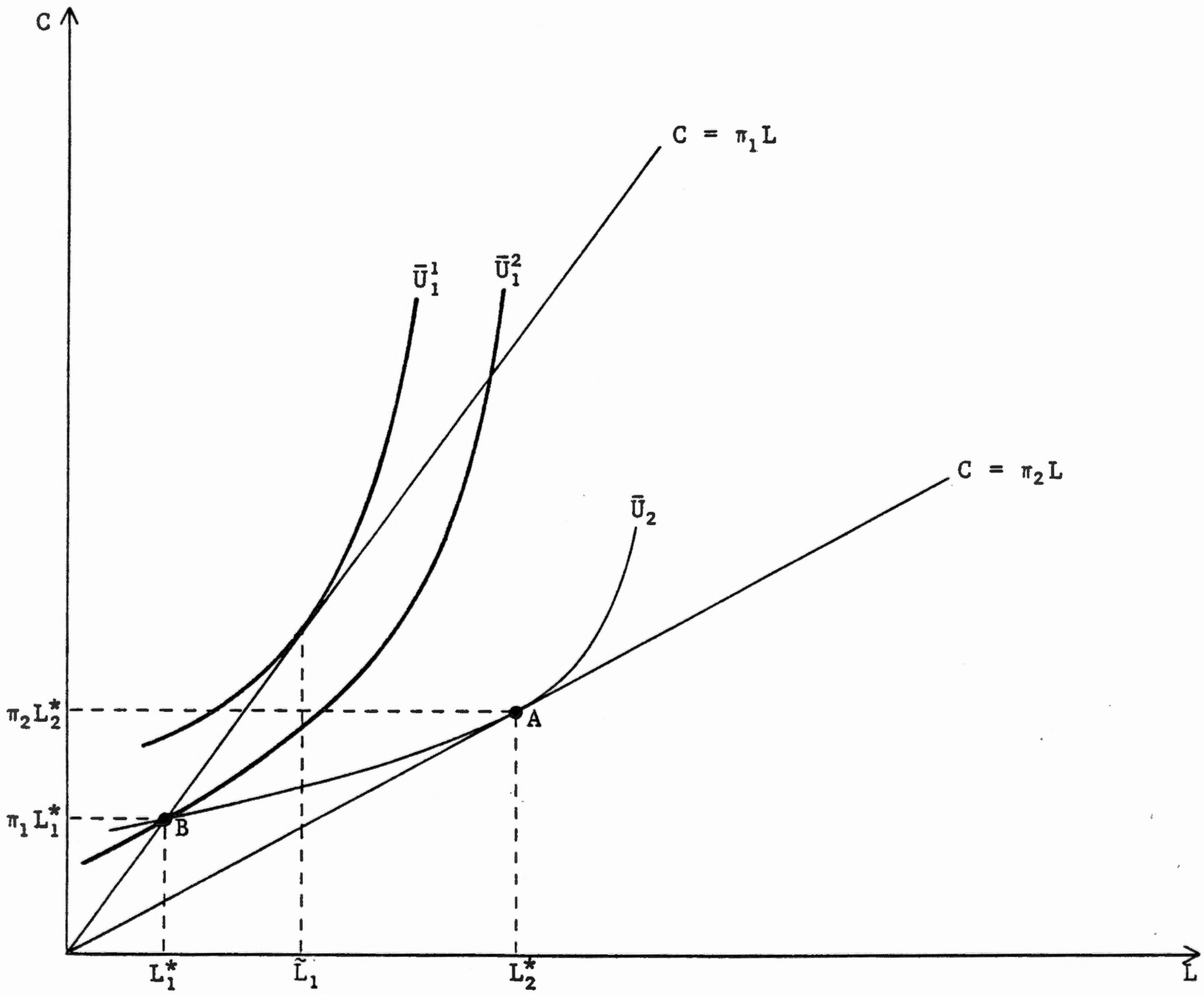
Figure 1

An Unemployment Equilibrium



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