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EQUILIBRIUM LONG-TERM LABOR CONTRACTS

by

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I. INTRODUCTION

Classical models of the labor market generally take the view that labor is exchanged for wage sequentially. Period by period wages clear the market by equating marginal product with the opportunity cost of labor, thereby assuring an efficient allocation of labor. That view has recently been challenged by the theory of implicit contracts (Azariadis [1975], Baily [1974], Gordon [1974]), which argues that labor transactions involve more than a continuous exchange of wage for productive inputs, because markets for contingent claims are incomplete. The worker, when faced with an uncertain income stream, has few opportunities to shed risk. Human capital is largely non-diversifiable and private insurance against income variation is rendered infeasible by moral hazard problems. A natural arrangement is to shift some of the income risk from the worker to the firm through a long term contract in which wage is less sensitive to demand fluctuations. Thus, labor contracts emerge as partial substitutes for missing securities markets, playing the dual role of compensating the worker for his services and providing him with insurance against undesirable income variation.

Firms find contracts beneficial, since they are a cheaper means to hire labor. The conclusion that contractual markets replace spot markets is an interesting one and suggests that wages we observe need not reflect instantaneous marginal product, because of the implicit insurance payment or premium embodied in contractual wages; in other words, contractual equilibrium may appear as disequilibrium in the short run. This challenges not only the traditional spot market view but also recent work on disequilibrium analysis, in which price and wage rigidities are associated with non-market clearing. For this reason it is apparent that the contractual view deserves careful consideration and indeed has received much attention lately (for a survey see

Azariadis, 1980a).

The purpose of this paper is to examine further the potential of contract theory by placing it in a consistent market equilibrium context. Most earlier work has been carried out in a partial equilibrium, single-period framework, assuming that labor is immobile subsequent to contracting.[1] In contrast, the main model to be presented here is a general equilibrium, multi-period model (initially two, later extended to any finite number of periods) without constraints on labor mobility. The motivation behind it is to get an understanding of the dynamics of a contractual market in which labor can be reallocated over time and to study to what extent contractual risk-sharing interferes with the efficient allocation of labor.

The basic model, which builds closely on Azariadis' (1975) work, is presented in section 2. Partial equilibrium results, characterizing the best long-term contract, are given in section 3. It is shown that despite non-convexities the optimal contract is unique (as needed for equilibrium analysis) and that a single contract is offered to all first-period workers. The optimal contract provides for downward rigid wages, rather than fully rigid wages, because I assume workers can quit in the second period if they can find higher income elsewhere (involuntary servitude is prohibited).[2] In addition to wage, employment is partly insured and job security created thereby is positively correlated with wage.

Labor market equilibrium is treated under two different assumptions about labor mobility, namely either labor cannot move at all or it can move at no cost. The first case, interpreted as arising due to firm specific skills, is analyzed in section 4. Compared to an appropriately defined Walrasian spot model, one finds that wage and labor paths are more stable and that workers enjoy a higher expected utility with long-term contracts. Firm owners may be worse off, but with lump sum transfers they can be compensated for a Pareto improvement. Socially, the allocation of skills (i.e. labor) is improved by introducing long-term contracts; since they reduce the bias against risky industries.

The paper's main model is presented in section 5. Here labor is allowed to move costlessly, which with firm specific uncertainties raises the possibility that labor will get reallocated in the second period. For this purpose a second period spot market opens. The natural notion of equilibrium to employ in this context is a rational expectations equilibrium, since expected second period market wages will affect the design of first period contracts and vice versa. I prove that such an equilibrium exists. The equilibrium differs in general from a sequential wage auction outcome, since the first period market is cleared by contracts. The fact that contracts emerge in equilibrium even without mobility costs deserves emphasis. It has widely been believed that when workers can quit at no cost, a contractual equilibrium collapses to the sequential wage auction outcome (see e.g. Baily, 1974).[3] This belief is an artifact of the single-period paradigm commonly used, which makes pre-payments feasible. With more than one period a worker can pay his insurance premium in advance by accepting a wage below marginal product.[4]

The contractual equilibrium I develop is much in the spirit of Radner's (1972) and Hart's (1975) original work on incomplete markets, with two distinguishing features. In my model securities are not exogenously given but created by firms in the form of contracts. Secondly, firm securities (contracts) are restricted to those who work with the firm in the initial period (contingent contracts for labor are not sold to outsiders).

The model accomodates both quits and layoffs. Quits will occur when workers can find better employment elsewhere. Layoffs occur for the same reason as in earlier models on implicit contract theory, namely the benefit offered by a third party to a laid off worker. In this case, however, it is the market that acts as a benefactor, which appears more appealing than reliance on unemployment benefits or the like. Nevertheless, without benefits exogenous to the market, there will be no unemployment; layoffs merely result in a transfer of labor between firms. This is so, because a contractual market will always have a lower rate of unemployment than a non-contractual one due to the fact that contracts partly insure employment in addition to wage.

Wages in the contractual equilibrium are downward rigid for those who are retained on a contract, but not generally for those who are laid off, since severance payments are institutionally ruled out (I comment on this assumption later). Therefore, in the aggregate the wage level need not be downward rigid. However, wages fluctuate less than in a sequential wage auction as contracts induce wages in the second period spot market to be uniformly higher than they would be without contracting.

A special feature of the model is that seniority classes arise endogenously from the multi-period paradigm. A firm may have homogenous workers do the same job at different wages (senior workers at higher wages) as some may be cashing in on their implicit insurance contract. These results complement (rather than duplicate) Grossman's (1977) results on seniority rules, which are derived from an exogenous assumption about worker reliability.

In section 6 I provide an extension to many periods. Markets open in each period for a possible reallocation of labor and all markets (except for the last) are contractual. Spot markets cannot co-exist with contract markets. Seniority rules extend to the multi-period case in a natural but interesting way; senior workers enjoy higher wages and higher job security. When admitted institutionally, they are furthermore protected by rights to be recalled at their old wage before any new workers are hired. This points to the difficulties newcomers face in finding jobs in the labor market. They are last in line for jobs, not because of productive differences, but merely because they arrived later.

In section 7 I discuss extensions and some critical issues including reputation, search costs, savings and severance payments. Section 8 contains concluding remarks.

2. THE MODEL

Consider an economy with a single consumption good produced by J firms, indexed $j=1,\ldots,J$. There are two types of consumers: owners and workers. Owners are identified with their firms. Workers are homogenous and for technical reasons represented by a continuum $(0,N)$. The economy extends over two periods (see section 6 for a T-period extension). In each period the economy will be in one of S mutually exclusive states $s=1,\ldots,S$. It is known which state prevails in the first period, whereas the second periodstate is uncertain. Objective, or agreed upon subjective probabilities $\phi_s \geq 0$, $\Sigma\phi_s = 1$, describe this uncertainty. It is convenient to distinguish both period and state by the same index s, so let $s=0$ represent the first period state.

Firms produce in both periods. They use labor as their single input. Production in state s by firm j is described by $f_{js}(\ell_{js})$ where ℓ_{js} is labor input. Since dependence on s is arbitrary, f_{js} could more generally be interpreted as firm profits excluding labor costs thereby accommodating uncertainties related to other input factors, which in this analysis are suppressed. Note that the labor input in the first period does not affect the second period production function.

I assume $f'_{j0}(0) = \infty$, $f'_{js} > 0$, $f''_{js} > 0$, and $f'_{js}(\ell_{js}) \to 0$ as $\ell_{js} \to \infty$. Recall that f_{j0} is first-period output according to our notational convention.

Firm owners are risk neutral. Their preferences for consumption are described by the expected utility:

$$U_j(c_0, c_1, \ldots, c_S) = c_0 + \sum_s c_s \phi_s, \quad \forall_j;$$

where c_0 is first-period consumption and c_s, $s \geqq 1$, second-period consumption in state s. In each period owners are assumed to be endowed with sufficient amounts of the consumption good so that bankruptcy considerations can be ignored.

Workers are identical. They have no consumption good endowment, but are endowed with one unit of labor in each period which they supply inelastically. A worker may at any time opt for working in his own household, which will give him $w_{0s} > 0$ of the consumption good in state $s=0,1,\ldots,S$. It is convenient to view the household as an additional firm, indexed j=0, with a constant returns to scale technology to which all workers have free access. Workers cannot store the consumption good from one period to the next, but will consume whatever they earn in each period.[5] By including possible value of leisure in w_{0s}, we may suppress the labor decision of workers and simply assume they always work in one of the firms $j=0,1,\ldots J$. Expected utility from contingent consumption for worker i is in that case:[6]

$$U_i(c_0, c_1, \ldots, c_S) = U(c_0) + \sum_s U(c_s)\phi_s, \quad i\varepsilon(0,N).$$

I assume $U' > 0$, $U'' < 0$, i.e. workers are risk averse.

Firms will hire workers in the first period, and may, depending on circumstances, lay off or hire additional workers in the second period. A first period contract $\delta=(w,r)$ specifies a wage vector $w=(w_0,w_1,\ldots,w_S)$ and a retainment probability vector $r=(r_1,\ldots,r_S)$, $0 \leqq r \leqq 1$, $s \geqq 1$. With this contract the worker receives a wage w_0 with certainty in the first period and a wage w_s in the second period if state s prevails and if he is not laid off. The probability that he is laid off in state s is $1 - r_s$. A second period contract is simply a wage paid for a unit supply of labor in the second period. This contract is not made until the second period state is revealed (contingent claims for labor are precluded except with the present firm).

It will be assumed that firms are reliable; they will not default on an agreed upon contract. The best way to understand this, is to view contracts as implicit, building on a certain reputation for reliability in the labor market. Workers, on the contrary, are assumed to quit in the second period if they can find better work.[7] Thus, a contract δ must specify a second period wage, which does not fall below w_{0s} in state s or, in case spot markets open, the wage established in that market. Let w_s^+ be the best alternative wage the worker can earn in the second period in state s and let $w^+ = (w_1^+,\ldots,w_S^+)$. Then a contract $\delta=(w,r)$ provides the worker with expected utility:

$$V(\delta) \equiv U(w_0) + \sum_s \{U(w_s)r_s + U(w_s^+)\ (1-r_s)\}\phi_s\ . \tag{1}$$

Feasibility requires $w_s \geqq w_s^+$, $s=1,\ldots,S$.

If the firm employs ℓ_0 workers in the first period on a contract $\delta=(w,r)$, and ℓ_s^+ additional workers in state s on a wage w_s^+, the firm's expected profit, and thereby the owner's expected utility is:[8]

$$\begin{aligned} W(\delta,\ell_0,\ell^+) \equiv f_0(\ell_0) - w_0\ell_0 + \Sigma\{f_s(\ell_0 r_s + \ell_s^+) - \\ w_s\ell_0 r_s - w_s^+\ell_s^+\}\phi_s. \end{aligned} \tag{2}$$

Since the firm views w^+ as an exogenous parameter, w^+ is suppressed in $W(\delta,\ell_0,\ell^+)$.

Some further notation is needed. Let $\ell^+ = (\ell_1^+,\ldots,\ell_S^+)$ be the vector of additional workers hired; let $\ell^r = (\ell_1^r,\ldots,\ell_S^r)$, with $\ell_s^r = \ell_0 r_s$, $s=1,\ldots,S$, be the vector of workers retained and let $\ell_s = (\ell_0,\ell_1,\ldots,\ell_S)$, with $\ell_s = \ell_s^r + \ell_s^+$, $s=1,\ldots,S$, be the vector of workers in total in the firm in each period and state. Define, $V_{min} = U(w_{00}) + \sum_s U(w_{0s})\phi_s$, which is the expected utility the worker can guarantee by himself, and $V_{max} = \lim_{w\to\infty} U(w) + \sum_s U(w)\phi_s = \lim_{w\to\infty} 2U(w)$. V_{max} may be infinite.

3. OPTIMAL CONTRACTS

As a preliminary step to the market equilibrium analysis we need to study how first-period contracts get determined. It is assumed that workers have complete knowledge of all contracts offered in the market in the first period, and hence will hoard at the firm with the best offer. If another firm wishes to hire workers it has to match this offer, say $\bar{\delta}$, by providing the worker expected utility at least equal to $V=V(\bar{\delta})$. The firm takes V as well as the second period alternative wage w^+ as given when it tries to determine its best contract offer in the first period by solving:

$$\text{(3)} \qquad \max_{(\delta,\ell_0,\ell^+)} W(\delta,\ell_0,\ell^+)$$

$$\text{s.t.} \quad \text{(i)} \quad V(\delta) \geqq V,$$

$$\text{(ii)} \quad w_s \geqq w_s^+, \; s=1,\ldots,S,$$

$$\text{(iii)} \quad 0 \leqq r_s \leqq 1, \; s=1,\ldots,S$$

(iv) $\ell_s^+ \geqq 0$, $s=1,\ldots,S$.

Note that if at an optimum $w_s = w_s^+$, both the firm and the worker will be indifferent between the number of workers laid off and the number rehired in state s; only ℓ_s will be determinate. This situation arises because mobility costs are zero. To avoid ambiguity, I will adopt the following convention:

(v) $w_s = w_s^+ \implies \ell_s^+(1-r_s) = 0$, $s=1,\ldots,S$.

This condition says that the firm will not substitute new workers for old ones if both groups claim the same wage.[9]

As stated, program (3) is a non-concave programming problem. Neither $W(\cdot)$ nor $V(\cdot)$ are concave. Nevertheless, the Pareto frontier is concave and the following theorem can be proved.

Theorem 1. The program in (3) has a unique solution. For every $V \varepsilon (V_{min}, V_{max})$ there exists a unique $\lambda = \lambda(V) > 0$, continuous and strictly increasing in V, such that the solution satisfies the necessary and sufficient conditions:

(4) $\lambda U'(w_0) = 1$,

(5) $w_s = \max\{w_0, w_s^+\}$, $s=1,\ldots,S$,

(6) $f_s'(\ell_s) - w_s + \frac{1}{U'(w_0)}[U(w_s)-U(w_s^+)] \geqq 0$, $s=1,\ldots,S$,
with equality if $w_s = w_s^+$ or $r_s < 1$,

(7) $f_0'(\ell_0) - w_0 + \sum_s\{f_s'(\ell_s) - w_s\}r_s\phi_s = 0$,

(8) $f_s'(\ell_s) - w_s^+ \leqq 0$, $s=1,\ldots,S$, with equality if $\ell_s^+ > 0$.

Proof: See Appendix.

Remark: If firms cannot hire additional workers in the second period, Theorem 1 remains valid with the restriction $\ell^+ = 0$ and with (8) removed.

Theorem 1 contains the central ingredients for the equlibrium analysis and will be discussed in more detail later, but a few observations are in order here. The characterization is a generalization of Azariadis (1975). Differences are due to the fact that here w_s^+ can vary with the state, workers may quit and new workers may be hired. The implication of quitting is that wages will not be fully rigid, but downard rigid (condition (5)). Firms have to raise wages to maintain labor in boom states. Downward rigidity is, of course, crucially dependent on the risk neutrality of owners and on the separability of worker preferences. Note that risk neutrality is not inconsistent with wage rigidity, though uniqueness of the solution to (3) is (cf. Baily, 1978).

Job separations may be effected both through quits and layoffs. Layoffs are determined by (6) (in equality form).[10] To understand (6), observe that an optimal solution to program (3) necessarily entails ex post Pareto optimality as a necessary condition for ex ante optimality, because contracts are state contingent. Thus, (6) equates the marginal rates of substitution between wage and retention probability of the firm and the worker. Intuitively, the rationale for layoffs lies in the benefit w^+ that is offered by a third party and which the firm-worker pair can get hold of only through a layoff. If there was no external benefit, i.e. $w_s^+ = 0$ for all s, (6) would always be satisfied as an inequality, and no layoffs would occur. This follows directly from ex post optimality or by noting that the function,

$$(9) \qquad g(w_0, w_s^+) \equiv w_s - \frac{1}{U'(w_0)} \{U(w_s) - U(w_s^+)\},$$

where $w_s = \max\{w_0, w_s^+\}$, achieves a maximum at $w_0 = w_s^+$. [11]

The other polar case occurs when workers are risk neutral. Then layoffs will take place up to the point where marginal product equals the outside benefit w_s^+; in other words, the labor force will be adjusted according to conditions for productive efficiency. In contrast, when workers are risk averse, as we have assumed, one has the following:

Corollary 1: If the firm lays off workers in state s and $w_0 > w_s^+$, then $f_s'(\ell_s) < w_s^+$. Hence, $\ell_s^+ > 0$ implies $r_s = 1$, $s \geqq 1$.

Proof: The maximum value of (9) was w_s^+ as noted above. When $w_0 > w_s^+$, $\partial g/\partial w_0 < 0$, since $U'' < 0$. The first claim follows by (6), the second by (8). Q.E.D.

The corollary shows that in addition to being insured against wage fluctuations, risk averse workers will also enjoy partial insurance against employment fluctuations.[12] They are retained beyond the point of productive efficiency. When workers finally are laid off, marginal product is so low that the firm would not be willing to hire new ones at the wage w_s^+, even if that was the level of unemployment benefits.

These results illustrate a central point: with long-term contracts, employment and wage decisions are being separated and hence differences in marginal product and wage will not determine employment adjustments. Consequently, contract theory and fixed-price models of the Barro-Grossman-

Malinvaud variety are inconsistent as indicated in the introduction. It is therefore false to suggest contract theory as a choice theoretic foundation for fixed-price modelling as has been done (e.g. Malinvaud, 1977).

The following theorem sheds some further light on the solution to (3) and indicates what the adjustment process will be for reaching market equilibrium.

Theorem 2. Let $\ell_0(V), \delta(V), \ell^+(V)$ be the unique solution to (3). Then $\ell_0(V), \delta(V), \ell^+(V)$ are continuous functions of V and

a. $\ell_0(V)$ is decreasing,

b. $w_0(V)$ is increasing,

c. $r_s(V)$ is non-decreasing,

d. $w^+(V)$ is non-decreasing,

e. $\ell_s^+(V)$ is non-decreasing.

Proof: See Appendix.

One finds that the comparative statics results for V are as expected. A higher expected utility for the worker implies increased labor costs with reduced labor demand as a consequence (a); thus the firm will rely more on second period recruitments (e); higher expected utility is provided partly by increasing wage and patly by improving security in accordance with the second-best nature of the contract (b,c,d). Thus, wage and job security are positively correlated.

A final property of long-term contracts should be noted. Implicit in the problem formulation (3) is the assumption that it does not pay the firm to segment workers into groups which are offered different contracts (yielding, of course, the same expected utility). This need not actually be assumed but can be proved as a consequence of optimal contracting. We have:

Theorem 3. It does not pay a firm to offer multiple contracts to identcal workers.[13]

Proof: See Appendix.

The intuition behind theorem 3 is simple. When a worker is paid more he will, by ex post optimality (see (6)) enjoy a higher level of security as well (the function g is decreasing). Therefore, a higher paid worker would enjoy a higher expected utility than a lower paid worker, contradicting the requirement that all enjoy the same market level of expected utility.

4. MARKET EQUILIBRIUM-SPECIALIZED SKILLS

Let me now put the labor contracting analysis in a market equilibrium framework by incorporating labor markets explicitly. Since labor is homogenous, there are only two markets: One at each date. An implication of the partial equilibrium analysis of the previous section is that the first period market will be contractual. Sequential auction markets are not sustainable, because foresighted firms would recognize that they could sell insurance together with employment, thereby getting labor more cheaply and this would induce others to follow. Indeed, with free entry (which we do not have), firms that do not engage in long term contracting would be forced out of the market.

The second period market will be a standard wage-mediated market, but only because there are no future dates (see section 6). In a model with infinite horizon, markets would at all dates be contractual. The need for future markets to open at all, obviously derives from a desire to reallocate labor.

Today's and tomorrow's markets will generally interact; expectations about future wages will affect what contracts are to be considered optimal today, and conversely, today's contracts will determine future wages. A standard methodology for bringing about a consistent notion of equilibrium in this situation is to work with self-fulfilling or rational expectations, which I will do.

There would be little difficulty in defining a general rational expecations equilibrium, which incorporated arbitrary fixed costs for labor movement. Yet, the analysis becomes more clear if two extreme cases, infinite mobility costs and zero mobility costs, are treated separately. I start with the former.

With infinite mobility costs there will be no second period market. One may interpret the situation so that workers acquire specialized skills in the specific firm they work for in the first period. The only alternative to being employed by the same firm in the second period is to stay home and receive w_{0s} as unemployment insurance, household income or an income equivalent for leisure. This income is independent of contracts formed in the first period, which simplifies the definition of an equilibrium.

Let $\Delta(w^+)$ be the set of feasible contracts satisfying (3) (ii) - (iii), and let $\bar{w}_0 = (w_{00}, w_{01}, \ldots, w_{0S})$ be the vector of income offered by the household.

Definition. A contractual equilibrium with specialized skills (CESS) is a number $V \varepsilon (V_{min}, V_{max})$ and a set of J pairs $\{(\ell_{j0}, \delta_j) | \delta_j \varepsilon \Delta(\bar{w}_0),\ \ell_{j0} \varepsilon \mathbb{R}_+;\ j=1,\ldots,J\}$ with properties

A1. $W(\ell_{j0},\delta_j) \geqq W(\hat{\ell}_{j0},\delta_j)$, for any $\hat{\ell}_{j0}\varepsilon \mathbb{R}_+$; for all $j=1,\ldots,J$.

A2. $W(\ell_{j0},\delta_j) < W(\ell_{j0},\hat{\delta}_j)$ implies $V(\hat{\delta}_j) < V(\delta_j)$, for any $\hat{\delta}_j\varepsilon\Delta(\bar{w}_0)$; for all $j=1,\ldots,J$.

A3. $V(\delta_j) = V$, for all $j=1,\ldots,J$.

A4. $\ell_{00} > 0$ only if $V = V_{min}$.

A5. $\sum_{j=0} \ell_{j0} = N$.

Conditions A1-A2 state that firms should choose an optimal contract-labor pair given a certain level of expected utility for the worker. Conditions A3-A4 are substitutes for market clearing. Without A3 workers would all line up at the firm(s) providing highest expected utility leaving others with no labor. Since $f'_{j0}(0) = \infty$, all firms will demand some labor regardless of the contract, and equilibrium would not obtain. A5 requires that labor demand and supply are equal; though if $V = V_{min}$, some workers may work for their own household (A4).

Note that $w_{js} \geqq w_{0s}$ by the requirement that δ_j is feasible, and that $\ell^+ = 0$, since there is no second period market. Recall the remark following Theorem 2, that (8) does not apply here. As an immediate consequence of Theorem 2 we have:

Theorem 4. There exists a unique CESS.

Proof. V will uniquely determine δ_j's and ℓ_{j0}'s satisfying A1-A3 and $\ell_{j0}(V)$ is continuously decreasing, by Theorem 2. Q.E.D.

CESS is the type of equilibrium generally envisioned in recent work on labor contracting (e.g. Azariadis [1975]). Because labor is not allowed to move and market equilibrium simply fixes V, most insights are gained already in a partial equilibrium analysis. Since (8) is not in effect, marginal product in the second period may be below or above wage, which indicates that the partial insurance market in this case operates well, but labor is misallocated. Some firms--those for which total expected marginal product exceeds expected wage outlays--will hoard labor in the first period since this is the only way by which firms can guarantee sufficient labor supply when the economy turns more favorable.

The absolute riskiness of firms will determine cost of labor. More risky firms have to compensate for more frequent adjustments in the level of production by paying higher wages. Some support for this can be found in the higher wages paid in cyclical durable goods industries (auto workers).

Consider now an economy for which labor is auctioned off in each period separately. Azariadis (1975) compares such an economy with the contractual. Under the assumption that firms are identical, he concludes that: (1) the auction market generates a more risky income stream but provides higher expected income; thus leaving ambiguous whether workers benefit from contracts after all; and (2) employment is at least as high in the contractual economy (and may be higher) as in the auction economy in all states of nature. Of course, total output is higher when labor is allocated in auction markets, because of production efficiency.[14]

With little effort one can validate these conclusions in our more general model when one maintains the assumption of identical firms. The somewhat surprising result that employment will be higher in the contractual market follows from Corollary 1; layoffs will occur only if marginal product falls strictly below w_{0s}, in which case spot markets will experience voluntary unemployment (see Akerlof and Myiazaki, 1980; Bryant, 1979). Expected income must be higher in auction markets, otherwise total first-period labor demand could not equal supply in the contractual market by comparing labor costs and using the concavity of the production function.

However, when firms are not identical it is inappropriate to compare CESS with an auction market that admits labor to move in the second period. For a proper comparison, the following definition of auction equilibrium is introduced:

Definition. An auction equilibrium with specialized skills (AESS) is a number $\tilde{V} \varepsilon (V_{min}, V_{max})$ and a set of pairs $\{(\tilde{\ell}_{j0}, \tilde{\delta}_j) | \tilde{\delta}_j \varepsilon \Delta(\bar{w}_0),\ \tilde{\ell}_{j0} \varepsilon \mathbb{R}_+;\ j=1,\ldots,J\}$ with properties:

B1. (i) $f'_{js}(\tilde{\ell}_{js}) - \tilde{w}_{js} = 0,$

(ii) $\tilde{\ell}_{js} \leqq \tilde{\ell}_{j0}$, and

(iii) $(\tilde{w}_{js} - w_{0s}) \cdot (\tilde{\ell}_{js} - \tilde{\ell}_{j0}) = 0;\ j=1,\ldots,J,\ s=0,\ldots,S$

B2. $W(\tilde{\ell}_{j0}, \tilde{\delta}_j) \geqq W(\ell_{j0}, \tilde{\delta}_j)$, for any $\ell_{j0} \varepsilon\ I_+$, $j=1,.\mathbb{R}.,J$.

B3. $V(\tilde{\delta}_j) = \tilde{V}$, for $j=1,\ldots,J$.

B4. $\ell_{00} > 0$ only if $\tilde{V} = V_{min}$.

B5. $\sum_{j=0} \tilde{\ell}_{j0} = N$.

Here workers cannot move in the second period. Markets are still wage-mediated and second-period wage will equal marginal product (as if there were many identical firms in an industry j within which mobility is allowed). First-period wage will be firm specific because workers will recognize that some firms are more risky than others in terms of second period pay; equilibrium requires that all firms offer the same expected utility (B3). Firms hire labor optimally (B2), but they do not design optimal long-term contracts; instead, second-period wage is determined by the number of workers hired in the first period (see B1[i]). Finally, the first period market has to clear (B5) and workers will join the household only in case firms cannot offer higher expected utility (B4).

I do not take the time to establish that AESS is a consistent notion of equilibrium; existence (and uniqueness) are easily proved. Note that when firms are identical AESS yields the same allocation of labor and wages as would an auction market with free mobility.

Comparing now AESS and CESS we cannot generally validate Azariadis' earlier mentioned conclusions. In particular, total employment may be lower in CESS than in AESS when firms are different. The reason for this is that labor will be allocated differently in the two market regimes; more risky firms will get a larger share of the labor pool when long-term contracts are allowed, and one can construct examples such that this results in an increased number of layoffs despite partial employment insurance. In contrast, we will see that with free mobility contractual markets employ uniformly more workers than auction markets.

A question of interest concerns the distribution of labor among firms in the auction and the contractual regime (i.e. the distribution of skills). Do long-term contracts improve the first-period labor (skill) allocation? Take the case of one riskless and one risky industry. Without contracts too many workers (from a productive point of view) will be working for the riskless industry, since it provides a safe wage. Once we admit long-term contracts, the risky industry can compete for labor more effectively (labor costs go down), whereas nothing is changed for the riskless industry (spot contracts equal long-term contracts). From theorem 5 below, the contractual equilibrium offers workers higher expected utility so the riskless industry must increase its wage, hence demand less labor. Consequently, more labor must end up in he risky industry when contracts are allowed. There will still be a bias towards the riskless industry if income varies in the risky sector (either due to layoffs or wage variation), as compared to the first-best situation, but the bias will be smaller than without contracts. I conclude:

Proposition. With two sectors, one riskless one risky, contracts will improve the allocation of skills among sectors from a productive point of view.

Of course, the proposition does not say anything about overall welfare. Considering workers alone we have:

Theorem 5. Workers prefer (weakly) the allocation in CESS to the allocation in AESS.

Proof. Suppose the claim were false, i.e. $V(\delta_j) < V(\tilde{\delta}_j)$ for all $j \geqq 1$ (by A3 and B3). By A5 and B5, $\ell_{k0} \leqq \tilde{\ell}_{k0}$ for some firm k. Let S_k be the set of states (possibly empty) in which layoffs (=quits) occur in firm k in the auction market (AESS). For $s \varepsilon S_k$, $\tilde{w}_{ks} = w_{0s}$, so the worker is indifferent towards changes in $\tilde{r}_{ks}$ in such states. Define $\delta_k^*(\varepsilon)$ to be equal to $\tilde{\delta}_k$ with the exception that for $s \varepsilon S_k$, set $r_{ks}^* = 0$, and in the first period let $w_{k0}^* = \tilde{w}_{k0} - \varepsilon$, $\varepsilon > 0$. By the contrapositive assumption $V(\delta_k^*(\varepsilon)) > V(\delta_j)$ if ε is small enough, so a worker prefers $\delta_k^*(\varepsilon)$ to δ_j.

For $s \notin S_k$, $\ell_{ks} = \ell_{k0}$ by Corollary 1. By B1, $f_{ks}'(\tilde{\ell}_{k0}) - \tilde{w}_{ks} = 0$, for s=0 and $s \notin S_k$. Since $\ell_{k0} \leqq \tilde{\ell}_{k0}$, $f_{ks}'(\ell_{k0}) - w_{ks}^* \geqq f_{ks}'(\tilde{\ell}_{k0}) = \tilde{w}_{ks} = 0$, for $s \neq 0$, $s \notin S_k (w_{ks}^* = \tilde{w}_{ks}$, $s \geqq 1)$. By construction, $f_{k0}'(\ell_{k0}) - w_{k0}^* > f_{k0}'(\ell_{k0}) - \tilde{w}_{k0} \geqq f_{k0}'(\tilde{\ell}_{k0}) - \tilde{w}_{k0} = 0$. Hence, signing some workers on the contract $\delta_k^*(\varepsilon)$ will have positive returns for the firm (recall that for

$s \varepsilon S_k$, $r^*_{ks} = 0$).

It has been established that in CESS at least one firm would find it more profitable to sign workers on two contracts (subject to A3) if workers preferred AESS to CESS. This contradicts A1-A2 via Theorem 3. Consequently, CESS must be at least as good as AESS for workers Q.E.D.

Since CESS and AESS may be equivalent, strict preference cannot be proved. Regarding firms it should be noted that profits need not be greater in CESS than in AESS; potential benefits from long-term contracts are destroyed by competition.[15] Thus, CESS and AESS cannot generally be Pareto ordered. However, two results regarding the efficiency of CESS can be stated. First, a CESS allocation cannot be Pareto improved under institutional constraints imposed (no labor mobility, no severance payment, no savings); this follows from the obvious fact that there is no reallocation of labor and contracts that would benefit all. Secondly, there exists a first-period lump-sum transfer from workers to firms such that when a new CESS is established after the lump-sum transfer has taken place, all parties are better off than they are in AESS. This is stated as:

Theorem 6. With first-period lump-sum transfers, CESS Pareto dominates AESS.

Proof: See Holmstrom (1980a).

5. MARKET EQUILIBRIUM-FREE MOBILITY

I turn now to the main model with costless mobility. Firms sign binding contracts in the first period. In the second period a standard auction market opens. All workers are free to move if they can find better pay. Laid-off workers automatically join the free market. An equilibrium is established in the second period spot market by equalling labor supply and demand. An equilibrium in the first period contractual market is based on expectations about second period wages. Full equilibrium is reached when these expectations lead to contracts which in fact will realize the expected second-period spot market wages, that is when expectations are fulfilled.

Let $V_{min}(w^+) = U(w_{00}) + \sum_s U(w_s^+)\phi_s$ and let $\Delta(w^+)$ be the set of feasible contracts that satisfy (3) (ii) and (iii). Formally we have

<u>Definition</u>. <u>A contractual equilibrium</u> (CE) consists of a pair (V,w^+), $V\varepsilon(V_{min},V_{max})\varepsilon\mathbb{R}$, $w^+ = (w_1^+,\ldots,w_S^+)\varepsilon\mathbb{R}_+^S$ and a set of three-tuples $\{\delta_j,\ell_{j0},\ell_j^+)|\delta_j\varepsilon\Delta(w^+),\ (\ell_{j0},\ell_j^+)\varepsilon\mathbb{R}_+^{1+S};\ j=1,\ldots,J\}$, with properties:

C1. $W(\delta_j,\ell_{j0},\ell_j^+) \geqq W_j(\delta_j,\hat{\ell}_{j0},\hat{\ell}_j^+)$, for any $\hat{\ell}_{j0}\varepsilon\mathbb{R}_+$; $\hat{\ell}_j^+\varepsilon\mathbb{R}_+^S$; $j=1,\ldots,J$.

C2. $W_j(\hat{\delta}_j,\ell_{j0},\ell_j^+) > W_j(\delta_j,\ell_{j0},\ell_j^+)$ implies
$V(\hat{\delta}_j) < V(\delta_j)$, for any $\hat{\delta}_j\varepsilon\Delta(w^+)$; $j=1,\ldots,J$.

C3. $V(\delta_j) = V$, for all $j=1,\ldots,J$.

C4. (i) $\ell_{00} = 0$, if $V > V_{min}(w^+)$, (ii) $\ell_{0s} = 0$, if $w_s^+ > w_{0s}$.

C5. $\sum_{j=0}^{J} \ell_{js} = N$, $s=0,1,\ldots,S$.

Given (V,w^+), C1-C2 state that firms make optimal contract and hiring decisions as characterized in (4)-(8); recall that w^+ is suppressed in the expression for expected profits of firms, $W_j(\delta_j,\ell_{j0},\ell_j^+)$. C3-C5 are conditions for market clearing. Without C3, workers would hoard at the firm(s) offering the highest expected utility, which could never be an equilibrium as $f'_{j0}(0) = \infty$ for all $j \geqq 1$. C4 (i) states that workers can be unemployed in the first period (i.e. stay with the household job) only if they have no better opportunity than to earn the household income w_{00} in that period and earn the spot wage in the second period. Similary, C4 (ii) states that there are unemployed in the second period in state s only if $w_s^+ = w_{0s}$. C4 is needed to complete the market clearing condition C5.

From C4-C5 it is clear that I view the labor markets in both periods as run by an auctioneer, though in the first period he will announce expected utilities rather than wages. This differs from approaches taken by Polemarchakis (1979), Polemarchakis and Weiss (1979) and Akerlof and Myiazaki (1980) who look at Nash equilibria.

Theorem 7. A contractual equilibrium CE exists.

Proof. By the proof of Theorem 2, $\ell_{j0}(V,w^+)$, $\ell_{js}(V,w^+)$, $j=0,\ldots,n$ are continous functions, bounded above because $w_{0s} > 0$ and $f'_{js}(\ell_{js}) \to 0$ as $\ell_{js} \to \infty$. Define:

$$g_0(V,w^+) = \max\{V + \ell_0^T(w^+,V) - N,\ V_{min}(w^+)\},$$

$$g_s(V,w^+) = \max\{w_s^+ + (\ell_s^T(w^+,V) - N),\ w_{0s}\},\ s=1,\ldots,S,$$

$$\text{where } \ell_s^T(w^+,V) = \sum_{j=1}^{J} \ell_{js}(w^+,V),\ s=0,1,\ldots,S.$$

The function $g = (g_0, g_1, \ldots, g_S)$ is a mapping from $\mathbb{R}_+^{1+S}$ to itself, is continous, and takes values in a compact set because ℓ_s^T:s are bounded. By Brower's theorem it has a fixed point, which easily is seen to be an equilibrium. Q.E.D

The question of whether a contractual equilibrium with free mobility is unique is still open.

The features of an equilibrium can better be discussed with the help of an example.

Example.

There are two firms with identical production functions $g(\ell) = 9-(\ell-3)^2$ when in operation. In the first period both firms operate so $f_{10} = f_{20} = g$. In the second period either firm may break down, in which case they are unable to produce. Specifically, $f_{11} = f_{22} \equiv 0$, $f_{12} = f_{21} = f_{13} = f_{23} = g$. When s=1, firm 1 is unable to produce; when s=2 firm 2 is unable to produce; when s=3 both firms produce as in the first period.

The labor pool size is N=2 and the worker's utility function is $U(w) = 9 - (w-5)^2$. $w_{0s} = 0$ for all s, so there is no household income.

In sequential spot market wages would be $(\tilde{w}_0,\tilde{w}_1,\tilde{w}_2,\tilde{w}_3) = (4,2,2,4)$ and employment $(\tilde{\ell}_{10},\tilde{\ell}_{11},\tilde{\ell}_{12},\tilde{\ell}_{13}) = (1,0,2,1)$, $(\tilde{\ell}_{20},\tilde{\ell}_{21},\tilde{\ell}_{22},\tilde{\ell}_{23}) = (1,2,0,1)$.

To calculate a contractual equilibrium one needs to know probabilities of the states. Initially, let $\phi_1,\phi_2,\phi_3 = 1-\phi_1-\phi_2$, be arbitrary. Equilibrium conditions are:[16]

(a) $\ell_{10} + \ell_{20} = 2$, by C5.

(b) $w_{10} = w_{12} = \dfrac{2(3-\ell_{10})+2\phi_2}{1+\phi_2}$; $w_{20} = w_{21} = \dfrac{2(3-\ell_{20})+2\phi_1}{1+\phi_1}$, by (7).

(c) $w_1^+ = w_2^+ = 2$, $w_3^+ = w_{13} = w_{23} = 4$, by (5), (8) and C5.

(d) $r_{11} = r_{22} = 0$; others = 1, by (6).

(e) $(1+\phi_2)U(w_{10}) = (1+\phi_1)U(w_{20})$, by C3.

(a), (b) and (e) determine the first-period labor allocation and guaranteed wage levels as functions of ϕ_1 and ϕ_2. If $\phi_1 = \phi_2 = \phi$ then $\ell_{10} = \ell_{20} = 1$ and $w_{10} = w_{20} = 2+2/(1+\phi) < 4$. When equilibrium exists, $w_{10}, w_{20} < 4$, and it is not hard to show that w_{10}, ℓ_{20} are increasing and w_{20}, ℓ_{10} decreasing in ϕ_1 and conversely for ϕ_2. Thus, firms pay different wages when $\phi_1 \neq \phi_2$.

In the second period, if a firm breaks down it lays off all workers and they join the other firm on a spot wage equal to 2. Old workers are still paid their first-period wage. If neither firm breaks down, wages are bid up to 4, which is the same as the equilibrium auction wage without contracts.

To give a numerical example of the non-symmetric case, let $\phi_1 = .12$ and $\phi_2 = .08$. The equilibrium has $w_{10} = 3.878$, $w_{20} = 3.761$, $\ell_{10} = .986$, $\ell_{20} = 1.014$, V=14.760, W_1=2.0922, W_2=2.3082, (expected profits for firms). For the sequential spot market, V=14.4, W_1=2.12, W_2=2.28.

Properties of equilibrium.

The example illustrates most of the central features of a contractual equilibrium with free mobility. We see, as I emphasized, that long-term contracts do emerge even without mobility costs in a two-period model.[17] The generally held belief that mobility costs are essential for the implicit contract argument (cf. Baily [1974]) is based on what happens in a single period model. In that case if workers quit when the labor market turns favorable, there is no opportunity for firms to offer insurance, because they never get to collect their share of the benefits. However, with two or more periods, workers can pay their insurance premiums in advance. This can be seen to happen in the present model by combining (7) and (8) to get:

$$(14) \qquad f'_{j0}(\ell_{j0}) = w_{j0} - \sum_{s\geq 1} \{ f'_{js}(\ell_{js}) - w_{js}\ell^r_{js} - w^+_s \ell^+_{js} \} \phi_s \geq w_{j0}.$$

Whenever there is insurance, (14) will be a strict inequality so that marginal product exceeds wage in the first period.

The point is that workers do not run after short run gains and therefore are not attracted by a firm who paid their marginal product in the first period but left them without a contract. This provides a choice theoretic foundation for worker reliability. As in the example, reliability is rewarded by seniority rules; senior workers receive in general a higher wage though they are no more productive than junior workers.[18]

Grossman (1977) has discussed the connection between seniority rules and reliability from a somewhat different perspective. In his model there are exogenously given reliable and non-reliable workers (perhaps because of different mobility costs). Time reveals who is who. Senior workers, who have not quitted, have revealed themselves as reliable. Grossman shows that reliable workers are more valuable and therefore will be offered a higher expected utility than unproven or unreliable workers. Consequently, they will be paid more and enjoy a higher level of security (cf. theorem 2).

The seniority rules suggested by my model are different and complement Grossman's. Senior workers are paid more simply because they arrived earlier and could sign a more favorable contract. For this reason, even workers of equal reliability could be paid differently if the two models were merged. A feature of the seniority priviledges of this paper is that they are reduced in upturns and expanded in downturns, i.e. they exhibit a countercyclical behavior which appears consistent with casual empiricism.

The contractual equilibrium can be compared to a classical auction equilibrium for the following observation:

Theorem 8. Employment and second period wages will be uniformly as high in a contractual market with free mobility as in a corresponding auction market.

Proof. Let $\tilde{w}_s, \tilde{\ell}_{js}$ be the sequential spot market wage and employment level of firm j in state s respectively. In a contractual equilibrium there will be unemployment in state s, $s \geqq 1$, only if $w_s^+ = w_{0s}$; this follows from C4 (ii). Suppose total employment, ℓ_s^T, in state s in a contractual equilibrium, falls below total employment, $\tilde{\ell}_s^T$, in the spot equilibrium. For some firm k, $\ell_{ks} < \tilde{\ell}_{ks}$ and hence $f'_{ks}(\ell_{ks}) > f'_{ks}(\tilde{\ell}_{ks}) = \tilde{w}_s \geqq w_{0s} = w_s^+$, contradicting (8). Hence, employment in the second period is uniformly higher with long-term contracts. It is easy to see that employment is always the same in the first period under the two market structures.

Suppose $\tilde{w}_s > w_s^+ \geqq w_{0s}$ for some s. It follows from the previous paragraph that $\ell_s^T = \tilde{\ell}_s^T$. From (8), $f'_{js}(\ell_{js}) \leqq w_s^+ < \tilde{w}_s = f'_{js}(\tilde{\ell}_{js})$, which implies $\ell_{js} > \tilde{\ell}_{js}$ for all $j \geqq 1$; a contradiction. Hence, $w_s^+ \geqq \tilde{w}_s$.

Q.E.D.

We find that in a CE wages in the second period will generally exceed auction market wages. The reason is simple: when firms commit themselves to retain workers beyond the point of productive efficiency (Corollary 1), a certain proportion of the labor force is withdrawn from the market, and so the reduced labor supply drives wages up. In contrast to the model with specialized skills, we see that free mobility always guarantees a higher employment level with long term contracts than without. The explanation is that firms will insure their workers against employment fluctuation as well as wage fluctuation (Corollary 1). This indicates that one should not think of implicit contracts as contributing to a higher level of unemployment.

The possibility that workers can find jobs in other firms and industries is certainly a significant aspect in determining labor contracts. The interplay between firms is well illustrated in the example; ϕ_2 affects directly w_1 and conversely for ϕ_1. Outside labor opportunities act to reduce labor costs for firms in the same way as an exogenous increase in unemployment insurance would. The strength of this effect will depend on the firm's relative riskiness, or in analogy with portfolio theory, its systematic risk (as opposed to absolute riskiness as in CESS). It is easy to check through program (3) that the less correlated a firm is with the market (w_s^+), the less are its labor costs. (I am proposing a comparative static result related to shifting probability mass from correlated states to non-correlated ones). Whether such portfolio considerations are significant factors in determining wage levels is up to empirical testing. From the worker's perspective one could say that in a certain sense human capital is diversifiable after all, namely by investing in a skill (or industry) which allows easy mobility.

An important consequence of the interplay between firms that is introduced by free labor mobility is the possibility of market supported layoffs. In previous models with implicit contracts, layoffs have always derived from unemployment benefits, value of leisure or some other exogenous source. This has been a source of both confusion and criticism. In the present model we may have layoffs without any benefits exogenous to the market, as the example illustrates. This may not seem terribly interesting at first sight, because there will still be full employment unless $w_{0s} > 0$ (layoffs only result in transfers). However, it takes little imagination to realize that in an extended model with search, the possibility of finding an outside job can play the role of a third-party benefit and induce layoffs with genuine unemployment as a consequence.

Welfare.

Let me finally turn to welfare aspects of a contractual equilibrium with free mobility. From Theorem 8 we conclude that workers are better off in the second period with long-term contracts than without--everybody will enjoy a (weakly) higher wage. However, (14) shows that first-period wage will be lower than in an auction market, which conceivably could offset second-period benefits. This is not the case in the example nor is it true in general. As in the model with specialized skills we have:

Theorem 9. Workers prefer (weakly) a contractual equilibrium (CE) to an auction equilibrium (AE).

Proof. Since employment is equal in the first period under both market regimes, there will be a firm k for which $\ell_{k0} \leqq \tilde{\ell}_{k0}$ (notation as in Theorem 8). Suppose $V(\delta_k) < V(\tilde{\delta})$, where $\tilde{\delta}$ is the sequential auction market "contract." Since $f'_{k0}(\ell_{k0}) \geqq f'_{k0}(\tilde{\ell}_{k0}) = \tilde{w}_0$, the firm would like to hire more labor in the first period if wage would be $\tilde{w}_0 - \varepsilon$, $\varepsilon > 0$. Let $\delta^*_k(\varepsilon)$ be a contract such that $w_{k0} = \tilde{w}_0 - \varepsilon$ and $r_{ks} = 0$ for all $s \geqq 1$. For $\varepsilon = 0$, $V(\delta^*_k(0)) \geqq V(\tilde{\delta}) > V(\delta_k)$, by the contrapositive assumption and the fact that $w^+_s \geqq \tilde{w}_s$ (Theorem 8). By continuity, there is an $\bar{\varepsilon} > 0$ such that $V(\delta^*_k(\bar{\varepsilon})) > V(\delta_k)$ and the firm is willing to hire some workers on $\delta^*_k(\bar{\varepsilon})$. According to Theorem 3, this contradicts the optimality of δ_k, i.e. A1-A2. Thus $V(\tilde{\delta}) \geqq V(\delta_k)$. Q.E.D

Owner's welfare change is ambiguous. In the example, the more risky firm becomes worse off and the less risky firm better off when moving from an auction market to a contractual market. As for CESS, one would expect that transfers from workers to firms would make CE Pareto dominate AE, but I have no general proof to offer. The line of proof in Theorem 6 works in case firms are identical but not generally.

The contractual equilibrium represents a compromise between auction markets (productively efficient) and CESS (risk shared efficiently). Full efficiency would result if one allowed transfers between firms (or severance payments) or what amounts to the same thing, if workers could be traded (a slave economy).[19] Reflecting the institutional constraints that are present, it is easy to show that CE is constrained efficient in the following sense: (i) given second period spot wages, there is no Pareto improving reallocation of contracts and labor in the first period, (ii) in any given second period state, there is no Pareto improving reallocation of labor and wages which do not involve transfer payments between firms.[20] In other words, a social planner acting independently in each period and state without the right to make transfer payments between firms could not improve a CE. This notion of constrained efficiency is taken from S. Grossman (1977) and is common for rational expectations models.

6. A MULTI-PERIOD EXTENSION

The two-period model may appear rather special and it seems appropriate to outline a multi-period extension. Let there be T+1 periods indexed $t=0,\dots,T$. States of nature are finite in number ($s=1,\dots,S$) and each state provides a complete description of the environment through all periods. Preferences of owners and workers are the obvious extensions of the two-period case. A firm's production function in period t, state s is given by $f_{ts}(\cdot)$, strictly concave and increasing. (I will only look at one firm so the firm index is suppressed). Let ℓ_s^τ = number of new workers hired in period τ, state s; r_{ts}^τ = fraction of workers of generation τ (hired in period τ) remaining in period t, state s; w_{ts}^τ = wage paid to workers of generation τ that are working in period t, state s. The firm's problem is to determine ℓ_s^τ, r_{ts}^τ, w_{ts}^τ for $\tau = 0,\ldots,T$, $t = \tau,\ldots,T$ and all s, subject to a number of constraints.

The first constraint concerns measurability of the choice variables. As in Hart (1975) it is assumed that uncertainty unfolds in a tree-like fashion. Let $\{S_t\}_{t=0}^{T}$ be a sequence of increasingly finer partitions of the state space, $S_t - S_{t+1}$, $S_0 = \Omega$, $S_T = \{(1),\ldots,(S)\}$. Let $S_t(s)$ be the element of the partition S_t containing s. Then it is required that all variables at time t be measurable with respect to S_t, i.e. be equal for s,s' such that $S_t(s) = S_t(s')$, as these states cannot be distinguished at time t. For instance, $\ell_s^\tau = \ell_{s'}^\tau$, for s,s' such that $S_\tau(s) = S_\tau(s')$.

The second constraint requires that $r_{ts}^\tau \geq r_{t's}^\tau$ for $t' > t$. This is based on the assumption that the fraction retained (out of the original number hired) is non-decreasing; once laid off, a worker will not be recalled (I will briefly discuss the option of recalls below).

The final constraint requires the firm to match or exceed market offers in order to retain workers. Let V_{ts} be the market determined expected utility level for newly hired workers in period t, state s. Write $w^\tau = (w_{ts}^\tau)$, $r^\tau = (r_{ts}^\tau)$ (w^τ, r^τ are $(T-\tau) \times S$ matrices) and $\delta^\tau = (w^\tau, r^\tau)$. The expected utility from being on a contract δ^τ in period $t \geqslant \tau$, state s is given by:

$$(15) \qquad V_{ts}(\delta^\tau) \equiv U(w_{ts}^\tau) + \sum_{n=t+1}^{T} E_{ts}\{[U(w_{ns}^\tau)r_{ns}^\tau + (r_{n-1,s}^\tau - r_{ns}^\tau)V_{ns}]/r_{ts}^\tau\},$$

where E_{ts} is the conditional expectation given $S_t(s)$. Then it is required that $V_{ts}(\delta^\tau) \geq V_{ts}$ for all $t \geq \tau$, all s. Rewriting (15) slightly , this can be phrased as:

$$(16) \qquad V_{ts}(\delta^\tau) - V_{ts} = \sum_{n=t}^{T} E_{ts}\{(U(w_{ns}^\tau) + (V_{n+1,s} - V_{ns}))r_{ns}^\tau / r_{ts}^\tau\} \geq 0.$$

The firm's objective, given market determined expected utilities V_{ts}, is then to:

$$(17) \qquad \max W(\delta^o,\ldots,\delta^\tau, \ell^o,\ldots, \ell^T) = \sum_{t=0}^{T} E_0\{f_{ts}(\sum_{\tau=0}^{t} \ell_s^\tau r_{ts}^\tau) - \sum_{\tau=0}^{t} w_{ts}^\tau \ell_{ts}^\tau r_{ts}^\tau\}$$

$$\text{s.t.} \qquad \begin{array}{ll} \text{(i)} & V_{ts}(\delta^\tau)r_{ts}^\tau \geq V_{ts}^\tau r_{ts}^\tau, \\ \text{(ii)} & r_{ts}^\tau \geq r_{t's}^\tau \qquad , \ t < t' \\ \text{(iii)} & \ell_s^\tau \geq 0. \end{array}$$

An equilibrium in the market is reached when (V_{ts}) are such that when firms solve (17) all labor markets clar. Existence of equilibrium can be proved by extending the arguments given for the two-period model. Note that all markets except the last one are contractual.

Some features of optimal contract design are of interest. Letting $\lambda_{ts}^\tau \ell_s^\tau \phi_{ts}$, where ϕ_{ts} is the conditional probability of state s given $S_t(s)$, be the Lagrange multipliers associated with constraints (i) we can write the Lagrangian (after some manipulations) as:

$$(18) \qquad L = \sum_{t=0}^{T} E_0\{f_{ts}(\sum_{\tau=0}^{T} \ell_s^\tau r_{ts}^\tau) - \sum_{\tau=0}^{T} w_{ts}^\tau \ell_{ts}^\tau r_{ts}^\tau\} +$$

$$\sum_{t=0}^{T} \sum_{\tau=0}^{t} E_0\{\bar{\lambda}^{\tau}_{ts}(U(w^{\tau}_{ts}) + (V_{t+1,s} - V_{ts}))r^{\tau}_{ts}\ell^{\tau}_{s}\},$$

where $\bar{\lambda}^{\tau}_{ts} = \sum_{n=\tau}^{t} \lambda^{t}_{ns}$. Differentiating (18) with respect to w^{τ}_{ts} gives:

$$(19) \qquad U'(w^{\tau}_{ts}) = 1/\bar{\lambda}^{\tau}_{ts}.$$

Since $\bar{\lambda}^{\tau}_{ts} \geq \bar{\lambda}^{\tau}_{t's}$ for $t > t'$, (19) tells us that wages are downward rigid for any realization of s. Differentiating (18) with respect to r^{τ}_{ts} gives (for an internal solution):

$$(20) \qquad f'_{ts} = w^{\tau}_{ts} - \frac{U(w^{\tau}_{ts}) + E_{ts}V_{t+1,s} - V_{ts}}{U'(w^{\tau}_{ts})}.$$

Here $\Delta V^{\tau}_{ts} \equiv U(w^{\tau}_{ts}) + E_{ts}V_{t+1,s} - V_{ts}$ is the difference in expected utility (conditional on $S_t(s)$) to a worker of generation τ from being laid off next period (t+1) rather than immediately (t). Since we must have $f'_{ts} \leq w^{\tau}_{ts}$ for layoffs, $\Delta V^{\tau}_{ts} \geq 0$ when workers of generation τ are laid off. This implies that the RHS in (20) is decreasing in w^{τ}_{ts}. Consequently, those with higher wage are never laid off before those with lower wage. A simple inductive argument shows, since wages are downard rigid, that workers of higher seniority must have at least as high wages as those of lower seniority (otherwise they would be both less secure and be paid less in contradiction to the fact that they once had the option to reduce their seniority by quitting), and therefore that workers of higher seniority are not laid off before all workers of lower seniority have been laid off. The intuition behind these results are that senior workers, who are on higher wage, are more expensive to lay off since it takes more money to compensate them for a marginal increse in lay off probability as their marginal utility for money is lower.

The firm will never hire workers in a period in which it lays off some. The reason is that since workers are homogenous, those laid off could be considered part of the newly hired ones. But this arrangement would imply that workers of same seniority would have different contracts which is suboptimal.

Finally, a comment on recalls. I omitted recalls because equilibrium is hard to define with them. In partial equilibrium, where laid off workers simply are idle, it can be shown that senior workers are laid off subsequent to junior workers and recalled before junior workers if both have been laid off. The argument is based on the fact that the firm's planning problem is solved so that the solution is always ex post optimal in any state and period and, as we already saw in the two-period model, ex post optimality requires that higher paid workers are never idle when lower paid workers are not. Furthermore, no new workers are hired before all old ones are recalled at old wages. This is indicative of a bias against young workers; they are always last in the que for jobs (except in newly created job openings) merely because they entered the market later. The feature of recalls may also help explain why the aggregate wage level in the economy (not just wages in individual contracts) is rather rigid downward - a feature that is not explained by (though erroneously associated with) earlier contract models.

7. SOME REMARKS ON ASSUMPTIONS.

In this section I will briefly take issue with some of the assumptions of the model.

Severance Payments.

I ruled out severance payments exogenously. If severance payments were allowed in the model firms would pay laid off workers the difference between their contract wage and w_s^+. This would fully insure the worker and lead to an equilibrium with allocational efficiency.

There are many reasons why such severance payments are not made.[21] The rationale that accords best with the analysis of this paper is that workers would have little or no incentive to search if they were fully compensated when laid off. It is indeed possible to include search costs explicitly into the model.[22] This would remove the need for an exogenous ban on severance payments and admit unemployment which is not created by exogenous benefits, but the general picture concerning wage and employment dynmaics would hardly change.

Reputation.

From (5) we see that firms should retain workers beyond the point of productive efficiency. One may ask, however, what would force the firm to behave in such a way, in particular since workers are unlikely to observe the firm's marginal product and be able to enforce the rule in (5). Reputation has been a reason generally alluded to and in Holmstrom (1980b) I provide a simple model in which the argument is made explicit. The point I make is that firms do not make either explicit or implicit promises concerning employment. Rather, a concern for its future ability to hire labor inexpensively (or of proper quality) forces the firm to treat its current labor force in a manner which appears as if an implicit contract was made beforehand. Not surprisingly, the degree to which reputation can police the firm depends on the rate of discount. If there is no discounting, optimal behavior coincides with the implicit contract outcome, whereas the myopic solution is approached as the discount rate goes to infinity.[23]

Of course, one could argue similarily that workers are concerned about a reputation for reliability and therefore are unlikely to breach the contract by quitting. Presumably a reputation for frequent quits carries a toll, but it is certainly finite and probably not even the biggest of mobility costs. A sufficient boom would still cause quits. As I mentioned before, fixed mobility costs could be incorporated in the model, but with the two extreme cases covered such an extension would provide limited additional insight.

Savings and Borrowing

Neither savings nor borrowing was allowed in the model described. Both would change the optimal contract design. Savings would lead to higher initial wages, part of which the worker would carry over to later periods as protection against layoffs. Savings opportunities do therefore reduce the need for severance payments. On the other hand, the firm cannot pay too high wages initially as this increases the chances for losing the worker in later periods. Exactly how these two considerations balance off in a multi-period context is unclear, but it seems plausible that the introduction of savings opportunities would not radically change the general picture with a long enough horizon.

Borrowing for self-insurance purposes is largely infeasible because the main source of a worker's collateral is his human capital. Moral hazard problems would arise if a firm offered to guarantee worker loans. Similar moral hazard problems prevent arrangements in which a worker who quits has to pay the firm a penalty. In the extreme a worker could stop working, forcing the firm to fire him instead.

Heterogenous Labor

Assuming that the labor force is homogenous is certainly unrealistic and on this point a very essential aspect of the labor market may be missed. If workers have observable differences so that different contracts can be made with different types, the analysis presented has an immediate extension. Equilibrium exists and its characteristics can be easily described similar to theorem 2. However, if workers are unobservably different we have a problem of adverse selection. It is well known that existence of equilibrium may be problematic and characterizing it, likewise. An extension in this direction appears a very difficult but worthwhile task.

8. CONCLUDING REMARKS

The purpose of the paper has been to explore the dynamics of a contractual labor market in an equilibrium setting. We find that in equilibrium long term contracts emerge with or without mobility costs. In the latter case contracts guarantee workers a downward rigid wage. A permanent strengthening of the economy causes contracts to be renegotiated and wages bid up. Thus, the market will operate like a ratchet. Through seniority rules, different generations of entrants may have different incomes; specifically, younger generations generally earn less, not because of productive differences but because they enter later. They also enjoy a lower degree of job security. That contracts create biases against young members of the labor force appears a robust and important feature of the model.

These implications of the model seem relevant in other contexts as well. Freeman (1977) pioneers an analysis of professional contracts, which can be extended to an equilibrium analysis as described here. More generally, the paradigm that is proposed here should be relevant for analyzing equilibrium models of agency relationships; for instance, the managerial labor market.

APPENDIX

Proofs of Theorems 1-3

As noted, there is a potential problem with proving uniqueness of program (3) as it is non-convex. What will be shown below is that the Pareto frontier nevertheless is strictly concave, so that a unique price will support each Pareto optimal solution. The methodology of the proof appears new. The idea is to show that for any $\lambda > 0$ the Lagrangian function has a unique solution. Geometrically it is then evident that the Pareto frontier must be strictly concave and that each point on the frontier must correspond to a single choice of (δ, ℓ^0, ℓ^+). This intuition is made rigorous below.

Lemma 1. There exists a solution to (3). Any solution will have $\ell_0 > 0$.

Proof. Since $f_s'(\ell_s) \to 0$ as $\ell_s \to \infty$ and $w_{0s} > 0$ for all s, the choice variables can be restricted to a compact set. The constraint set i) - (iv) is closed. Thus, by continuity, program (3) (i) - (iv) has a solution, which clearly can be made to satisfy (v). Since $f_0'(0) = \infty$, we have $\ell_0 > 0$ for any solution.

Q.E.D.

Instead of looking at program (3) we can study the equivalent problem:

(A-1) $$\max_{(\delta, \ell_0, \ell^+)} W(\delta, \ell_0, \ell^+),$$

s.t. (i) $V(\delta)\ell_0 \geq V\ell_0$,

(ii) $w_s \geq w_s^+$,

(iii) $0 \leq r_s \leq 1$,

(iv) $\ell_s^+ \geqq 0$,

(v) $w_s = w_s^+ \Rightarrow \ell_s^+(1-r_s^+) = 0$

Define the Lagrangian program corresponding to (A-1) as:

$$\text{(A-2)} \qquad \max_{(\delta,\ell_0\ell^+)} \quad W(\delta,\ell_0,\ell^+) + \lambda\ell_0(V(\delta)-V)$$

s.t. (ii) - (v) above.

<u>Lemma 2.</u> Program (A-2) has a unique solution for all $\lambda > 0$.

<u>Proof.</u> The maximand in (A-2) reads:

$$\text{(A-3)} \qquad \begin{aligned} & f_0(\ell_0) - w_0\ell_0 + \lambda U(w_0)\ell_0 + \sum_s \{ f_s(\ell_s^r + \ell_s^+) - w_s\ell_s - w_s^+\ell_s^+ \\ & + \lambda\left(U(w_s)\ell_s^r + U(w_s^+)\ (\ell_0 - \ell_s^r)\right) \} - \lambda\ell_0 V. \end{aligned}$$

Regardless of (ℓ_0,ℓ^r,ℓ^+), the wage vector is uniquely determined by conditions (4) and (5). The wage thus determined, a maximal solution exists for the same reason as in Lemma 1. Furthermore, the remaining program is concave in (ℓ_0, ℓ^r, ℓ^+) and the constraints on these variables form a convex set. By strict concavity of f_0 and f_s, maximization yields a unique value for $\ell = (\ell_0,\ell_1,\ldots,\ell_S)$. It remains to check that $\ell_s^r + \ell_s^+ = \ell_s$ does not allow a continuum of choices for pairs (ℓ_s^r,ℓ_s^+).

Consider the function $g(w_0, w_s^+)$ defined in (9). We have $g(w_0,w_s^+) < w_s^+$ if $w_0 > w_s^+$, and $g(w_0,w_s^+) = w_s^+$ if $w_0 \leqq w_s^+$. Since $-g$ is the coefficient in front of ℓ_s^r in (A-3), it follows that $\ell_s^+ = 0$, $\ell_s^r = \ell_s$ if $w_0 > w_s^+$.

When $w_0 \leqq w_s^+$ so that $w_s = w_s^+$, (A-2) (v) applies. In either case, (A-2) has a unique solution.

Q.E.D

Let $(\ell_0(\lambda), \ell^r(\lambda), \ell^+(\lambda), w(\lambda))$ denote the unique solution to (A-2) given λ, and write $r_s(\lambda) = \ell_0(\lambda)\ell_s^r(\lambda)$, $\ell_s(\lambda) = \ell^r(\lambda) + \ell^+(\lambda)$, $\delta(\lambda) = (w(\lambda), r(\lambda))$ and $V(\lambda) = V(\delta(\lambda))$. By Theorem 1.8 (4) of Debreu, these functions are all continuous in λ.

<u>Lemma 3.</u> For every $V \varepsilon (V_{min}, V_{max})$ there exists a <u>unique</u> λ-value, $\lambda(V)$, such that program (A-2) solves program (A-1) and thereby the original program (3). $\lambda(V)$ is a continuous, strictly increasing function of V.

<u>Proof.</u> $V(0) = V_{min}$, and as $\lambda \to \infty$, $V(\lambda) \to V_{max}$. By continuity of $V(\lambda)$ there exists a λ-value, λ^*, for which $V(\lambda^*) = V$. By duality, the corresponding solution to (A-2), $(\delta(\lambda^*), \ell_0(\lambda^*), \ell^+(\lambda^*))$, is optimal for (A-1).

Suppose there were another λ, $\hat{\lambda} \neq \lambda^*$, such that $(\delta(\hat{\lambda}), \ell_0(\hat{\lambda}), \ell^+(\hat{\lambda}))$ solves (A-1). Then $V(\hat{\lambda}) = V(\lambda^*) = V$ or else one could merely change w_0 to get a contradiction. Consequently, the maximal value of the objective function in (A-2) is the same for both λ-values, and so $(\delta(\lambda^*), \ell_0(\lambda^*), \ell^+(\lambda^*))$ solves (A-2) with $\lambda = \hat{\lambda}$ as well. By Lemma 2, $\delta(\lambda^*) = \delta(\hat{\lambda})$, which contradicts the fact that $U'(w_0(\lambda))\lambda = 1$, as $U'' < 0$.

$V(\lambda)$ is certainly non-decreasing and by the argument above it is strictly increasing. Thus its inverse, $\lambda(V)$ is strictly increasing for $V \varepsilon (v_{min}, V_{max})$, and continuous because $V(\lambda)$ is continuous.

Q.E.D

Proof of Theorem 1. By Lemma 3, there exists a (unique) λ-value such that program (3) can be solved via program (A-2). Simple rearrangements of first-order conditions to (A-2) give (4)-(8), noting that constraint (i) will always be binding. Program (3) has a unique solution, since if there were another solution not generated via (A-2), that solution would also solve (A-2) as (i) must be binding; a contradiction to Lemma 2.

Q.E.D

Proof of Theorem 2. I will first argue more generally that optimal contract variables vary continuously with the parameters (V,w^+). Consider program (3) without condition (v). From the proof of Lemma 2 it follows that (ℓ,w) are uniquely determined even without (v), though pairs (ℓ_s^r, ℓ_s^+) may not. Since the constraint set (i)-(iv) is a continuous point-to-set map (from (V,w^+) to feasible points), Theorem 1.8.(4) of Debreu implies that optimal (ℓ,w)-values vary continuously with (V,w^+). By (3) (v), $\ell_s^+ = \max(0,\ell_s - \ell_0)$ and $\ell_s^r = \ell_s - \ell_s^+$, making them as well uniquely determined and continuous in (V,w^+) along the optimum.

Given continuity, statement (b) and (d) follow from (4) and (5) and Lemma 3. Regarding (a), note that $\ell_0(V)$ cannot be increasing for all V (clearly $\ell_0 \to 0$ as $V \to V_{max}$). Hence if (a) were false, there would exist two values $V_1 > V_2$ such that $\ell_0(V_1) = \ell_0(V_2)$. From (b) and (6), $r_s(V_2) < r_s(V_1)$, $\forall s$. Together with (b), (d) and Corollary 1, $\ell_0(V_1) = \ell_0(V_2)$ then contradicts (7). Finally, (c) follows from (6) by (d), and (e) follows from statement (a) noting Corollary 1.

Q.E.D.

Proof of Theorem 3. Suppose the firm offers n different contracts, all yielding the same expected utility to workers. A necessary condition for these n contracts to be optimal is that each contract offered is optimal when the (n-1) other contracts are kept fixed (including the number of employees hired on these contracts). For such suboptimization a characterization (4)-(8) applies for some λ, though these λ's may potentially differ for different contracts. However, note that ℓ_0 and ℓ_s in (6)-(8) will be the same for the different characterizatons--namely the total labor force of the firm (on any contract) in each state. But then different λ's for different contracts would imply different welfare levels for workers on different contracts (higher λ would imply higher wage and at least as high job security according to Theorem 2). This is a contradiction.

Q.E.D.

Footnotes

1. Exceptions include Polemarchakis (1979) and Polemarchakis and Weiss (1978), which provide a different equilibrium analysis, and Freeman (1977), whose partial equilibrium analysis of a single-worker, two-period model admits costless quitting.

2. Downard rigid wage is a feature in Freeman (1977) as well.

3. Baily's model is multi-period, but I suspect that the intuition behind the argument for mobility costs stems from a single-period paradigm

4. A more subtle reason for the necessity of mobility costs is that without them firms would be insuring social risks alone. Therefore, the model without mobility costs is best thought of as describing an industry rather than the whole economy.

5. See section 7 for remarks on saving and borrowing.

6. With virtually no modifications one could include a discount factor, but it would have to be the same for owners and workers. See, however, later remarks on the connection between discounting and reputation.

7. I will comment on this asymmetric assumption regarding reputation and reliability in section 7.

8. When discussing a firm in general the firm index is dropped.

9. Note that the statement is conditional on $w_s = w_s^+$. It will be shown that at an optimum it holds true also for $w_s > w_s^+$.

10. The following necessary and sufficient condition for layoffs to be desirable can be derived as in Azariadis (1975):

$$f_s'(\ell_0^*) < w_s^* - \left(U(w_s^*) - U(w_s^+)\right) \frac{1}{U'(w_s^*)},$$

some $s \geqq 1$. Here (ℓ_0^*, w^*) is the best full employment contract guaranteeing expected utility V.

11. This conclusion would be altered if taxes were considered. For instance, risk neutral workers would be laid off when taxes exceeded marginal product. This observation is due to Feldstein (1976).

12. Full income insurance is not provided through severance payments as those are institutionally ruled out. See section 7.

13. Azariadis (1975) conjectures this result.

14 Strictly speaking, Azariadis' verbal conclusion was that there is underemployment, which is incorrect, but his mathematical analysis is correct. Azariadis reasoned that total output, hence employment, must be higher in an auction model because of productive efficiency. The mistake is that total output, which includes home production but not industry output, is higher. In the contractual

world too many workers work for firms rather than at home.

15. The reader can look at the following example. There are two states. In the good state production is $f(\ell) = \ell^{\alpha}$, in the bad state it is $\beta f(\ell)$, with $\beta < 1$. The initial state is good. All firms are alike. This example has the property that firm owners are strictly worse off in CESS for any choice of worker utility function and household income which results in layoffs.

16. $f_{11} = f_{22} = 0$ violates our assumption of strict concavity and indeed this causes non-existence problems. The equilibrium is characterized by (a)-(e) provided the solution has $w_{10}, w_{20} < 4$; otherwise there is no equilibrium. If ϕ_1 and ϕ_2 are close enough, equilibrium exists.

17. The two situations in which an auction market equilibrium will coincide with a contractual equilibrium is if $V = V_{min}$, or when there is no aggregate uncertainty and consequently no need for insurance.

18. Notice that implicit in the optimal contract is an optimal design of deferred payments, which usually are thought of as deterrants to quitting. That we observe explicitly deferred payments in the real world is part of the enforcability problem with implicit contracts.

19. It is interesting to note that in some professional sports markets labor is traded in this way.

20. This includes a restriction not to exchange workers between firms in a cycle, because with workers in different wage categories this could amount to transfer payments being carried out.

21. We observe, of course, both implicit and explicit severance payments in the real world. In particular, advance notice on layoffs and payment of unemployment benefits should be viewed as part of a severance package. Yet, they hardly compensate workers completely.

22. Burdett and Mortensen (1980) present a model with search that is rather different from what I have in mind, since labor is never transferred between firms (only newcomers search). Arnott, Hosios and Stiglitz (1980) look at the incentive - insurance tradeoff that I am referring to.

23. In a departure from implicit contract models, Azariadis (1980), Chari (1980), Green (1980) and Grossman and Hart (1980) pursue an analysis of employment contingent contracts as an optimal solution to incentive problems related to asymmetric information. This provides an alternative approach to enforcability, which has a number of interesting implications including involuntary unemployment and incomplete severance.

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